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PACKAGE IV

SENIOR DIVISION

Ministry of Education
Ontario

Hon. Bette Stephenson, M.D., Minister
Harry K. Fisher, Deputy Minister

Plus

PHYSICS: PACKAGE IV

SENIOR DIVISION

THE ONTARIO ASSESSMENT INSTRUMENT POOL

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Queen's Park
Toronto, Ontario

ISBN 0-7743-9197-9
ISSN 0228-0957
ON 03301

This package contains laboratory-skill test instruments, and laboratory-experiment test instruments. Some of the instruments are suitable for use in evaluating the aims, goals, and objectives of Senior Division Physics, some for evaluating the aims, goals, and objectives of courses at the Ontario Academic Credit level, and some at both levels. Additional materials will be distributed as they become available.

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Kinds of Laboratory Test Instruments

There are two kinds of laboratory instruments in this package: laboratory-skill test instruments, and laboratory-experiment test instruments.

Laboratory-Skill Test Instruments

Laboratory-skill test instruments enable the teacher to evaluate students' skill in using common laboratory equipment. The Subject Advisory Group believes that the skill instruments should be used only after students have been taught the skills and have practised them. The format for arranging the instruments is referred to as a bell-ringer test. A number of different test stations are arranged around the room. Question cards and equipment are placed at each station. The student reads the question and makes a straightforward measurement using the equipment. At suitable intervals (say every five minutes) the teacher uses a bell to signal students to move on to the next station; hence the name bell-ringer.

In the bell-ringer tests students are observed while using various science instruments and a mark is assigned on the basis of their ability to use the instrument correctly to a degree of accuracy determined by the teacher. In order to have a standard of accuracy for comparison, the teacher can generally use the class histogram and the mean, mode, or median of the results, depending on the shape of the distribution. Alternately, the teacher can use the science instruments to determine a value and can compare the students' results to this value.

Laboratory-Experiment Test Instruments

A laboratory-experiment test instrument presents a problem and requires the student to design and implement a procedure to solve the problem and to report the results. The Subject Advisory Group feels laboratory-experiment test instruments may be used either before or after the topic has been taught. The test may present an entirely new situation and challenge the student to design a procedure to solve a problem. In this case

the laboratory-experiment test instrument is being used as a teaching tool. At the other extreme, the test may be a repetition of a laboratory exercise that has already been performed. Ideally, however, the test instrument presents a slightly new situation in the sense that it requires a modest extension, or modification, of work already done.

To standardize the scoring procedure, OAIP: Physics uses the same format for all laboratory-experiment test instruments. Also, the form of the answer has been standardized through the provision of a common answer sheet.

Each laboratory-experiment test instrument consists of a note to the teacher, an introduction, a statement of the problem, a list of materials, and an outline of the sequence to be followed in solving the problem and writing up the report. The test is broken into two parts.

In "Part A - Experiment Design", the students have a specified amount of time to state the problem, examine the materials, draw a diagram, and list the main steps of the method proposed for solving the problem. Suggested times are provided in the "Notes to the Teacher" which accompany each instrument. Blank spaces have been left in the instrument for the teacher to enter times (s)he thinks appropriate. The form of the student's answer is standardized by means of a common answer sheet, titled "Part A - Experiment Design". Students are to answer using the headings: "Problem", "Diagram", and "Method". The student submits the answer sheet to the examiner before starting Part B.

At the beginning of "Part B - Experiment Report", the examiner provides the student with the procedure to be followed. Alternately, the examiner may choose to let the student use his/her own procedure, if it is judged to be complete and safe. The student is also given an answer sheet titled "Part B - Experiment Report". A specified amount of time is allowed for performing the procedure and reporting the results. The report is to be organized under the headings: "Observations", "Calculations", "Accuracy", and "Conclusion".

Where an instrument does not require "Calculations" and/or "Accuracy", the section has been omitted.

Masters for Making Answer Sheets

The two masters for making answer sheets have been included. The teacher may choose to reproduce the answer sheets in their present form, or may type in the appropriate headings from those listed earlier before making copies.

Administering Laboratory Test Instruments

Laboratory tests should foster creativity or at least activity on the part of each student, rather than the passivity that is sometimes possible when a student is a member of a group. Most of the laboratory test instruments can be used by individuals working alone. (There are a few exceptions.) However, this arrangement presents a logistical problem. How does a teacher arrange for each member of the class to perform a test? And what steps can the teacher take to minimize the passing of procedural ideas (orally or visually) from student to student? We think that there are several possibilities.

a) The teacher may require the students to do "Part A - Experiment Design" for the test as a paper-and-pencil exercise a day or more before the date of the test. This should ensure more effective use of the time during the test period.

b) Since a teacher is not likely to have available thirty sets of apparatus for one particular test, and if several short tests are available, several different stations may be set up in the laboratory. Students rotate to the different stations in turn. However, even with this arrangement, it will probably be impossible to have each member of the class busy at a test at any given time. The section that follows addresses this problem.

c) Activity must be provided for those students not actively engaged in performing the test. Here creativity on the part of the teacher is necessary - creativity that we find

difficult to outline because so much depends on the size of the classroom and the layout of the facilities in the room. The following are methods that have been used successfully.

(i) The class may be set to work on an assignment such as the working of numerical problems, the completion of laboratory reports, library research, finalizing of notes, summarizing or reviewing the unit, etc. A limited number of students may then be withdrawn at intervals to perform the laboratory test.

(ii) A variation of (i) above is that half the class may be writing the normal test for the unit while the other half performs the laboratory test.

(iii) A variation of (ii) might be that one item on the unit test is practical, and each student is given a time during the test period to carry out this laboratory part. Four or five stations involving an identical measurement may be set up for this purpose. However, the stations should be designed so that the likely value is different at each station.

(iv) An extension of the procedure in (ii) is possible if the testing is done over two days. One-half of the class does the written portion and one-half does the laboratory portion on each of the two days.

The number of possibilities seems large. Admittedly, none of them eliminates all of the potential problems, but the advantages of laboratory tests are sufficiently great to warrant their use.

Scoring Laboratory-Experiment Test Instruments

The scoring policy for OAIP: Physics laboratory-experiment test instruments has been standardized through the use of a common scoring scheme for all instruments. The scoring scheme combines the characteristics of a checklist and a rating scale.

A checklist is a measuring device used to record whether an element is present or absent. The element is scored either full marks or zero. The checklist is quantified by counting up the marks.

A rating scale is used to evaluate attributes that can be measured in terms of degrees. It consists of a set of attributes to be judged and a scale indicating the degree to which each attribute is present. It provides a common framework for comparing all students on the same set of characteristics and provides a convenient method of recording the judgement and comments of observers. A numerical rating scale includes a set of numbers beside each attribute. The rater circles the number that indicates the degree to which each attribute is present. The final grade is obtained by summing the circled numbers.

A scoring scheme for laboratory-experiment test instruments and a scoring scheme for graphs are shown on the following pages. When a graph is part of the test, the total of the graph score is divided by five before the score is entered in the laboratory test instrument scale. If no graph is involved, the scorer circles NA on the scoring scheme for laboratory test instruments and decreases the total accordingly. Space is provided in the comments section of the scoring scheme for written comments which clarify the score obtained and provide remediation suggestions.

An example of a completed scoring scheme for a laboratory-experiment which involves a graph is shown on the next page. Remediation comments are included.

Completed Sample

Scoring Scheme for Graphs

Laboratory Test Instrument: *Force Constant of a Spring*

Candidate's Name: *"Very Good Person"*

	Attribute	Scale
1.	The graph has an appropriate title.	0 1 (2)
2.	The dependent (or appropriate) variable is plotted on the vertical axis.	0 (2)
3.	The quantities are labelled correctly on the axes.	0 1 (2)
4.	The correct units are shown on the axes.	0 (1) 2
5.	The scale of the graph is appropriate.	0 1 2 (3) 4
6.	The points are plotted accurately.	0 1 2 (3) 4
7.	The error for the points is appropriately shown.	0 1 (2)
8.	The curve is appropriate for the trend.	0 1 2 (3) 4
9.	The graph is neat.	0 1 (2) 3
	Total	*20* /25 = *4/5*

Comments: *The newton, not the kilogram, is the unit of force. Choose convenient axis divisions for the graph. One point was plotted incorrectly. Your line of best fit needs some adjustment.*

In general, a well done graph. However, try to be a little neater.

Completed Sample

Scoring Scheme for Laboratory-Experiment Test Instruments

Laboratory Test Instrument: *Force Constant of a Spring*

Candidate's Name: *"Very Good Person"*

	Attribute	Scale
	Part A - Experiment Design	
1.	Statement of the problem.	0 1 (2)
2.	Labelled diagram showing experiment set-up.	NA 0 1 (2) 3
3.	Steps of the method.	0 1 2 3 (4) 5
	Part B - Laboratory Performance	
4.	Skill in using common laboratory materials and instruments.	0 1 (2) 3
5.	Performance of common laboratory techniques with care and safety.	0 (1) 2
	- Experiment Report	
6.	Organization and completeness of the observations.	0 1 2 3 (4) 5
7.	Graph. (See scoring scheme for graphs divided by five.)	NA 0 1 2 3 (4) 5
8.	Calculations: Knowledge of relationships, calculations, and correct use of units.	NA 0 1 2 3 (4) 5
9.	Discussion of sources of error.	NA 0 1 (2) 3 4 5
10.	Conclusion and discussion of the validity of the answer.	0 1 2 3 (4) 5
	Total	*29/ 40*

Comments: *Label the diagram. You forgot to stress hanging masses in steps from the spring. Correct for parallax when reading scales. Clamp the retort stand firmly in place. Place units only at the top of each column in the chart. Include units with numerals in calculations. See me about sources of error in this experiment.*

A very good effort.

Scoring Scheme for Graphs

Laboratory Test Instrument: _____

Candidate's Name: _____

	Attribute	Scale
1.	The graph has an appropriate title.	0 1 2
2.	The dependent (or appropriate) variable is plotted on the vertical axis.	0 2
3.	The quantities are labelled correctly on the axes.	0 1 2
4.	The correct units are shown on the axes.	0 1 2
5.	The scale of the graph is appropriate.	0 1 2 3 4
6.	The points are plotted accurately.	0 1 2 3 4
7.	The error for the points is appropriately shown.	0 1 2
8.	The curve is appropriate for the trend.	0 1 2 3 4
9.	The graph is neat.	0 1 2 3
	Total	/25

Comments: _____

_____

_____

_____

_____

_____

Scoring Scheme for Laboratory-Experiment Test Instruments

Laboratory Test Instrument: _____

Candidate's Name: _____

	Attribute	Scale
	Part A - Experiment Design	
1.	Statement of the problem.	0 1 2
2.	Labelled diagram showing experiment set-up.	NA 0 1 2 3
3.	Steps of the method.	0 1 2 3 4 5
	Part B - Laboratory Performance	
4.	Skill in using common laboratory materials and instruments.	0 1 2 3
5.	Performance of common laboratory techniques with care and safety.	0 1 2
	- Experiment Report	
6.	Organization and completeness of the observations.	0 1 2 3 4 5
7.	Graph. (See scoring scheme for graphs divided by five.)	NA 0 1 2 3 4 5
8.	Calculations: Knowledge of relationships, calculations, and correct use of units.	NA 0 1 2 3 4 5
9.	Discussion of sources of error.	NA 0 1 2 3 4 5
10.	Conclusion and discussion of the validity of the answer.	0 1 2 3 4 5
	Total	/

Comments: _____

_____

_____

_____

_____

ANSWER SHEET

Laboratory Test Instrument: _____

Candidate's Name: _____

PART A - EXPERIMENT DESIGN

Organize the experiment design under the following headings: Problem, Diagram, Method. Use the front and back of this sheet if necessary.

ANSWER SHEET

Laboratory Test Instrument: _____

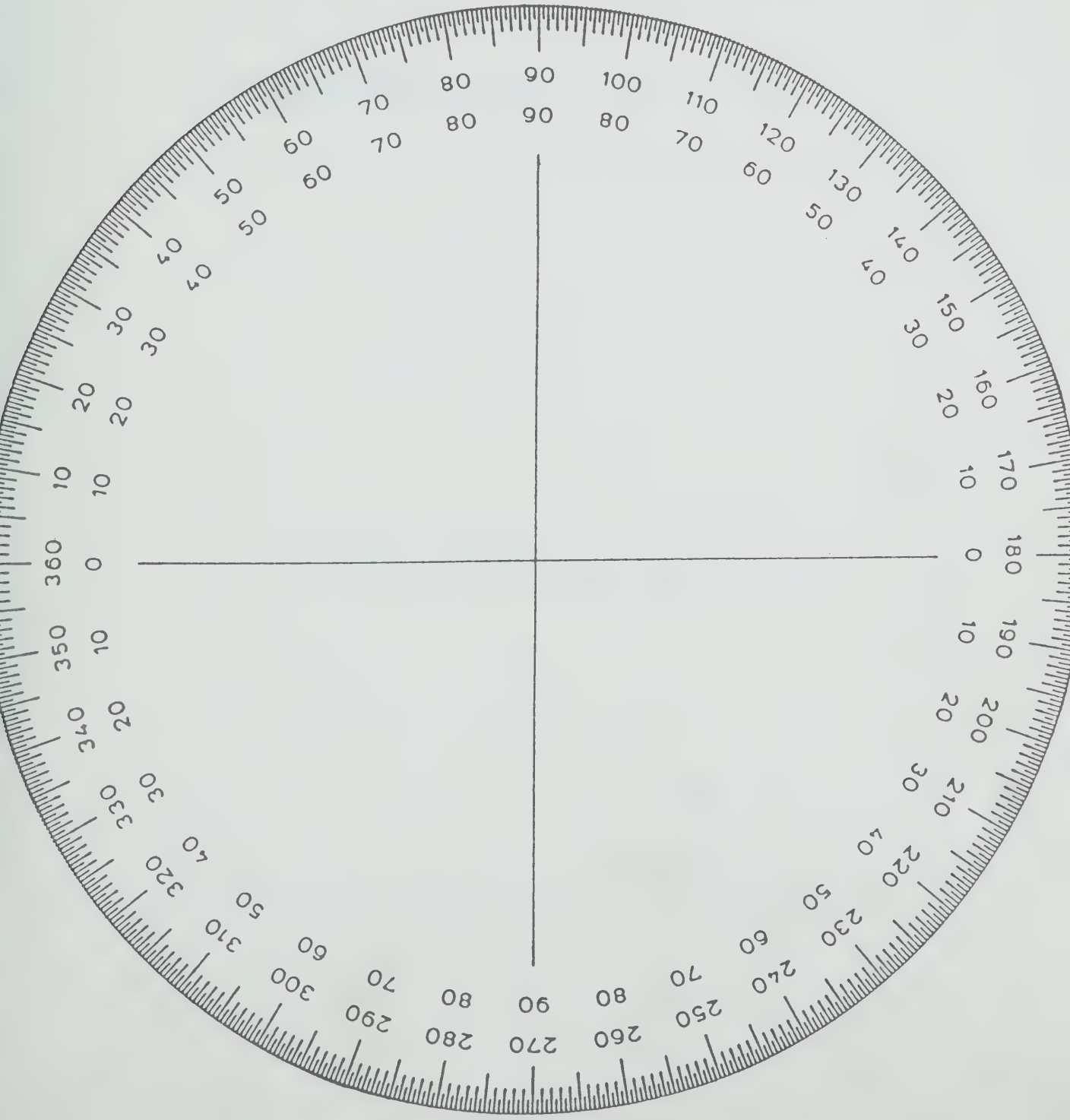
Candidate's Name: _____

PART B - EXPERIMENT REPORT

Organize the experiment report under the following headings: Observations, Calculations (where appropriate), Accuracy, Conclusion. Use the front and back of this sheet if necessary.

Polar Co-ordinate Master

Teachers will find this master useful for making polar graph paper to use in optics experiments involving the measurement of angles of incidence, reflection and refraction. This master is less cluttered than other masters and enables the student to measure angles directly. Teach students where to position materials on the paper for easy reading.



LABORATORY - SKILL

TEST

INSTRUMENTS

Notes to the Teacher

S17A
I.1.a

1. A desk surface is ideal provided the length is over one metre and the width is under one metre.
2. Provide a metre stick calibrated in millimetres.

2
4

3. Delete the last sentence in the problem statement for students in basic and general level programs.

B3

*
-
*

LABORATORY-SKILL TEST INSTRUMENT 1

LENGTH AND WIDTH

Problem

Measure the length and width in centimetres of the rectangular shaped surface. Record the likely value and the uncertainty in each measurement.

Materials

metre stick

rectangular surface specified by your teacher

Notes to the Teacher

S17A
I.1.a

1. A desk surface is ideal.
2. Provide a metre stick calibrated in millimetres.
3. Delete the second and third paragraphs from the problem statement for students in basic and general level programs.

2
3
4
8

B3

*
-
*

LABORATORY-SKILL TEST INSTRUMENT 2

AREA OF A RECTANGULAR SURFACE

Problem

Determine the area of the rectangular surface in square centimetres.

First record, in centimetres, the measured value and the uncertainty of each linear measurement.

Then calculate the area. Show the likely value and the percent uncertainty in the area. Show all calculations.

Materials

metre stick

rectangular surface specified by your teacher

Notes to the Teacher

S17C
I.1.a

1. Use a pad of paper with the pages attached together along one edge.
2. Provide a metric ruler calibrated in millimetres.
3. Do not provide a micrometer screw gauge.

2
4

B3

*
-
*

LABORATORY-SKILL TEST INSTRUMENT 3

THICKNESS OF A SINGLE SHEET OF PAPER IN A PAD

Problem

Design and implement a method to determine the thickness in millimetres of a single sheet of paper from the pad. Record all measurements and calculations.

Materials

metric ruler

thick pad of paper

Notes to the Teacher

S17A
I.1.a
2
4
B3

*
-
*

1. Provide a single sheet of paper.
2. Students should have used a micrometer screw gauge previously.
3. Do not provide a metric ruler.
4. Delete the second sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 4

THICKNESS OF A SINGLE SHEET OF PAPER

Problem

Design and implement a method to determine the thickness in millimetres of the single sheet of paper. Record the likely value and the uncertainty in the measurement.

Materials

micrometer screw gauge

sheet of paper

Notes to the Teacher

S17A
I.1.a

2
4

B3

*
-
*

1. Provide a coin or a cylindrical solid, such as a cylindrical magnet.
2. Students should have used vernier calipers previously.
3. Delete the second sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 5

DIAMETER OF A CYLINDER

Problem

Measure and record the diameter of the cylinder provided. Record the likely value and the uncertainty in the measurement.

Materials

cylindrical solid

vernier calipers

Notes to the Teacher

S17A
I.1.a

1. Provide a protractor calibrated in degrees.
2. Delete the second sentence of the problem statement for students in general and basic level programs.

2
4

B3

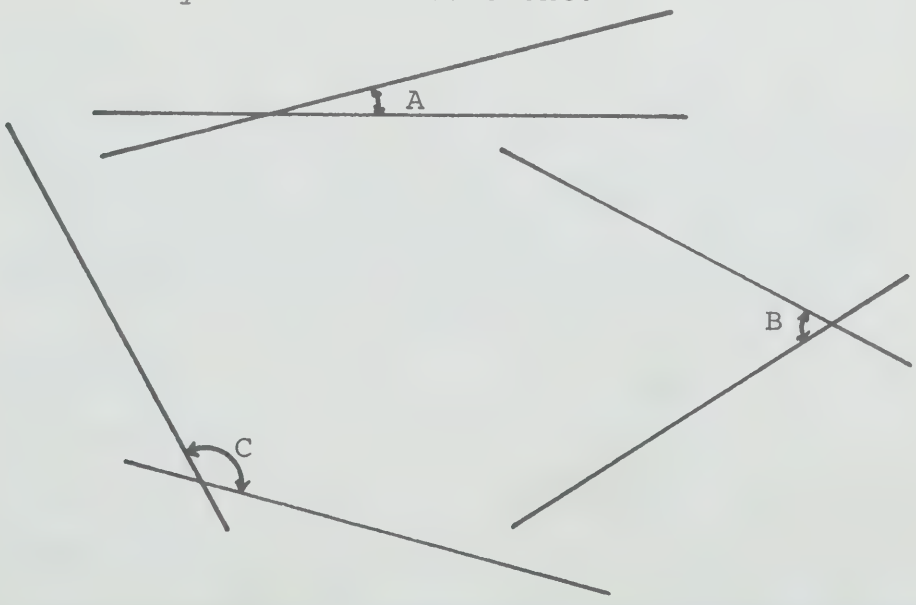
*
-
*

LABORATORY-SKILL TEST INSTRUMENT 6

ANGLES

Problem

Measure the angles labelled A, B, and C on the diagram below. Record the likely value and the uncertainty in each measurement.



Materials

protractor

Notes to the Teacher

S17A
I.1.b

1. Record on an audio tape the sound of two sharp clicks, separated by several seconds of silence.
2. Record the first click at least 5 s from the beginning of the tape.

2

3. Use a cassette tape player with a consistent speed.

3

4. Provide a stop watch calibrated in 0.1 s or 0.2 s. The uncertainty of the result will depend on the calibration of the stop watch.

4

B3

5. Several stations could be set up around the room by providing cassette tapes with different time intervals and stop watches with different scale divisions.

*
–

6. Delete the last sentence of the problem statement for students in general and basic level programs.

*

LABORATORY-SKILL TEST INSTRUMENT 7

TIME INTERVAL

Problem

The sounds of two sharp clicks, separated by a short time interval, are recorded on the cassette tape provided. Turn on the cassette player and listen to the clicks. Measure the time interval in seconds between the two clicks. Record your measurement of time. Include both the likely value and the uncertainty in the measurement.

Materials

pre-recorded tape

stop watch

tape recorder

Notes to the Teacher

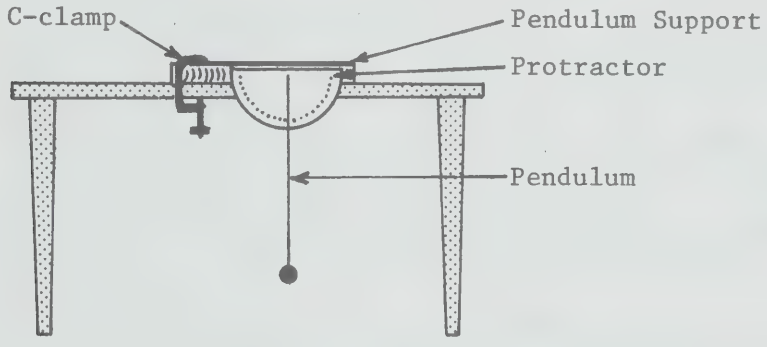
S17A
I.1.b

1. Explain the term 'period' if students have not studied this previously.

2
3
4

2. Use a pendulum of length between 25 cm and 100 cm. This yields a period between 1 s and 2 s.
3. The pendulum can be set up using a protractor, pendulum support, and C-clamp as shown below.

B3



**
-
**

4. Delete the last sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 8

PERIOD OF A PENDULUM

Problem

Pull the pendulum aside 20° and release it. Determine the period of the pendulum. Be sure to record all measurements and show all calculations. Record the likely value and the uncertainty in the measurement.

Materials

C-clamp

pendulum support

protractor

stop watch

string pendulum

Notes to the Teacher

S17A
I.1.a
2
4
B3
*
-
*

1. Use only a Celsius thermometer.
2. Provide a thermometer subdivided in 1°C or 2°C intervals. The uncertainty of the measurement will depend on the subdivisions of the thermometer.
3. To ensure that the temperature reading does not vary from your expected value, you could use one of the following procedures.
   a) Use a clinical thermometer.
   b) Remove the bulb and fluid from a broken thermometer and insert a fine wire to simulate the fluid. Reseal the end with epoxy.
   c) Remove the bulb and top from a broken thermometer and draw some coloured paint up the bore so as to leave a permanent mark on the inside of the tube.
4. Several stations can be set up around the room by providing thermometers with different temperature readings and different subdivisions.
5. Delete the last sentence from the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 9

TEMPERATURE

Problem

Read the temperature indicated by the thermometer. Record the likely value and the uncertainty in the measurement.

Materials

Celsius thermometer

Notes to the Teacher

S17A
I.1.a

2
3
4
8

B3

*
-
*

1. The shape of the bottom of a sandal drawn on cardboard and cut out yields an ideal irregular shape.
2. Provide the students with centimetre graph paper. Graph paper divided into millimetres is more accurate, but takes too long.

LABORATORY-SKILL TEST INSTRUMENT **10**

AREA OF AN IRREGULAR-SHAPED SURFACE

Problem

Design and implement a method to determine the area of the irregular-shaped surface in square centimetres. Record your answer.

Materials

centimetre graph paper

irregular-shaped surface

Notes to the Teacher

S17A
I.1.b
2
4
B3
*
-
*

1. Provide a mass within the range of the balance.
2. Zero the balance ahead of time and tell the students not to adjust the zero.
3. If more than one station is used, vary the object to be measured and provide different kinds of balances (triple beam balance, vernier balance).
4. Delete the last sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 11

MASS OF A SOLID OBJECT

Problem

Determine the mass of the solid object in grams. Record the likely value and the uncertainty in the measurement.

Materials

balance

solid object

Notes to the Teacher

S17A
I.1.b

1. Provide the sand in a beaker. Measure the mass before and after to determine if any sand was lost.
2. The mass of the sand plus beaker should be within the range of the balance.

2
4

3. The students will have to subtract the mass of the beaker from the mass of the beaker plus sand.

B3

4. If more than one station is used, vary the amount of sand and provide different kinds of balances.

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5. Delete the last sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 12

MASS OF A SMALL AMOUNT OF SAND

Problem

Design and implement a method to determine the mass of sand in grams contained in the beaker. Record the likely value and the uncertainty in the answer.

Materials

balance

empty beaker

sand in a beaker

Notes to the Teacher

S17A
I.1.b
2
4
B3
*
-
*

1. Provide the sand in a beaker. Measure it before and after to determine if any sand was lost.
2. Provide a mass of sand larger than the range of the balance but less than twice the range of the balance.
3. Zero the balance ahead of time and instruct the students not to adjust the zero.
4. If more than one station is used, vary the amount of sand and provide different kinds of balances (triple beam balance, vernier balance).
5. Delete the last sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 13

MASS OF A LARGE AMOUNT OF SAND

Problem

Design and implement a method to determine the total mass in grams of the sand in the beaker. Record the likely value and the uncertainty in the answer.

Materials

balance

empty beakers

sand in a beaker

Notes to the Teacher

S17A
I.1.a

1. The rectangular solid should have all linear measurements different and no measurement larger than 30 cm.
2. Provide a 30 cm metric ruler divided in millimetres.
3. Delete the first sentence in the second paragraph of the problem statement for students in general and basic level programs.

2
3
4
8

B3

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-
*

LABORATORY-SKILL TEST INSTRUMENT 14

VOLUME OF A RECTANGULAR SOLID

Problem

Make the necessary measurements to determine the volume of the rectangular solid in cubic centimetres. Record each measurement.

Determine the likely value and the percent error in the volume. Show all calculations.

Materials

metric ruler

rectangular solid

Notes to the Teacher

S17A
I.1.a
2
4
B3

1. If more than one station is set up, supply different volumes of liquids to be measured and different sizes of graduated cylinders.
2. Caution the student not to disturb the cylinder.
3. Use coloured liquids to facilitate viewing.
4. Delete the last sentence of the problem statement for students in general and basic level programs.

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LABORATORY-SKILL TEST INSTRUMENT 15

VOLUME OF A SMALL AMOUNT OF LIQUID

Problem

Read the volume of the liquid in the graduated cylinder. Record the likely volume in millilitres and the uncertainty in the measurement.

Materials

graduated cylinder partially filled with a liquid

Notes to the Teacher

S17A
I.1.a
2
4
B3
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-
*

1. Provide a volume of liquid between 110 mL and 190 mL.
2. If more than one station is set up, supply different volumes of liquids to be measured and different sizes of graduated cylinders.
3. Colour the water to facilitate viewing.
4. Some students may decide to use the 400 mL beaker to measure the volume. Provide an uncalibrated beaker to prevent this.
5. Provide a new sample of liquid for each trial since some liquid may be spilled during the measuring process.
6. Delete the last sentence of the problem statement for students in general and basic level courses.

LABORATORY-SKILL TEST INSTRUMENT **16**

VOLUME OF A LARGE AMOUNT OF LIQUID

Problem

Design and implement a method to determine the total volume in millilitres of the liquid in the container. Record the likely volume and the uncertainty in the volume.

Materials

sample of liquid in an uncalibrated container

100 mL graduated cylinder

400 mL beaker

Notes to the Teacher

S17A
I.2.c
2
4
35
B3
*
-
*

1. Check the calibration of the spring scale ahead of time.
2. Use spring scales calibrated in newtons.
3. Provide an object whose weight is within the range of the spring scale.
4. If more than one station is set up, supply objects of different mass, and spring scales with different scale divisions and ranges.
5. Check the calibration and zeroing of the spring scales after each use since these may change.
6. Delete the last sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 17

FORCE OF GRAVITY USING A SPRING SCALE

Problem

Determine the force of gravity, in newtons, acting on the object. Record the likely value and the uncertainty in the measurement.

Materials

object

spring scale

thread

Notes to the Teacher

S17A
I.2.c
2
4
35
B3
*
-
*

1. Check the calibration of the spring scales ahead of time.
2. Use spring scales calibrated in newtons.
3. Provide an object whose weight is within the range of the two spring scales connected in parallel.
4. If more than one station is set up, supply objects of different mass and spring scales with different scale divisions and ranges.
5. Delete the second sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 18

FORCE OF GRAVITY USING TWO SPRING SCALES

Problem

Design and implement a method to determine the total force of gravity in newtons on the object. Record the likely value and the uncertainty in the force of gravity. Sketch the arrangement of the balances and threads used to take the reading.

Materials

object

two spring scales

two threads

Notes to the Teacher

S17A
I.2.c
2
4
35
B3
*
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*

1. Check the calibration of the spring scale ahead of time.
2. Use a spring scale calibrated in newtons.
3. Provide objects whose weights singly are within the range of the spring scale, but whose combined weight is beyond the range of the spring scale.
4. If more than one station is set up, supply objects of different mass and spring scales with different scale divisions and ranges.
5. Delete the last sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT 19

COMBINING FORCES OF GRAVITY

Problem

Design and implement a method to determine the combined force of gravity in newtons on the objects provided. Record the likely value and the uncertainty in the total force of gravity.

Materials

objects

spring scale

thread

Notes to the Teacher

S17A
III.2.c

2
4
101

A7
B3

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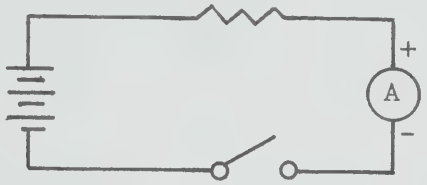
1. Prewire the circuit as shown below.



2. Use a source whose electric potential stays constant, such as fresh dry cells or a D.C. power supply.
3. Use a resistor that doesn't change resistance for the electrical potential used, such as nichrome wire or wire wound resistors.
4. Zero the ammeter ahead of time, and if possible use an ammeter with a single scale.
5. If a multi-scale meter is used, instruct students to record the scale used to take the reading.
6. If more than one station is set up, supply different resistances and ammeters with different divisions and ranges.
7. Mask the code on the resistors.
8. Use small currents (large resistors) to minimize the drain on the battery.
9. Delete the last sentence of the problem statement for students in general and basic level programs.

LABORATORY-SKILL TEST INSTRUMENT **20**

ELECTRIC CURRENT

Problem

Measure the electric current that flows through the circuit after the switch is closed. Record the likely value and the uncertainty in the electric current.

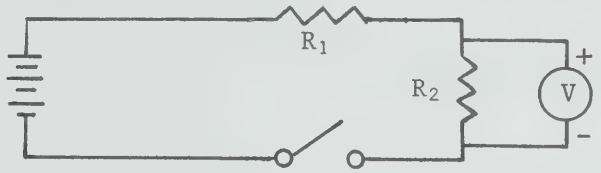
Materials

ammeter
connecting wires
constant voltage source
resistor
switch

Notes to the Teacher

S17A
III.2.c

1. Prewire the electric circuit as shown below.



2
4
101

A7
B3

2. Use a source whose electric potential stays constant, such as fresh dry cells or a D.C. power supply.
3. Make R_2 significantly different from R_1.
4. Zero the voltmeter ahead of time.
5. If more than one station is set up, supply different resistances and voltmeters with different ranges.
6. Delete the last sentence of the problem statement for students in general and basic level programs.

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LABORATORY-SKILL TEST INSTRUMENT 21

ELECTRIC POTENTIAL DIFFERENCE

Problem

Determine the voltmeter reading after the switch is closed. Record the likely value and the uncertainty in the electric potential difference.

Materials

connecting wires

constant voltage source

2 resistors

switch

voltmeter

Notes to the Teacher

S17A
III.2.c
2
4
101
A7
B3

1. Do not provide a circuit diagram.
2. Caution the students against closing the switch.
3. Consider using an inoperable source. Remove the fuse from the power supply to make it inoperable.
4. Evaluate the polarity and placement of the ammeter and voltmeter and the open switch.
5. There are two possible solutions: ammeter connected inside the voltmeter loop and ammeter connected outside the voltmeter loop.

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LABORATORY-SKILL TEST INSTRUMENT 22

CONNECTING A CIRCUIT WITHOUT A CIRCUIT DIAGRAM

Problem

Connect a circuit to measure the electric current through the load and the electric potential difference across the load. Do not close the switch.

Materials

ammeter	light bulb and socket (load)
connecting wires	switch
D.C. source	voltmeter

CAUTION: DO NOT CLOSE THE SWITCH.

Notes to the Teacher

S17A
III.3.a
203
A7
*
-
*

1. Demagnetize the magnetic material by heating it in the flame of a Bunsen burner.
2. Mark one end of the magnetic material N.
3. Provide a strong permanent magnet with unmarked poles.
4. Use a magnetic material that will retain its magnetism once magnetized, such as a large cement nail, or a steel knitting needle. Avoid soft iron.
5. Check the polarity of the compass.
6. Provide a new sample of magnetic material for each student.

LABORATORY-SKILL TEST INSTRUMENT 23

MAKING A PERMANENT MAGNET USING ANOTHER MAGNET

Problem

Imagine that you are working for a company that makes permanent magnets. The foreman has asked you to make a magnetic material into a magnet such that the end marked N is a north seeking pole.

Materials

compass

magnetic material with one end marked N

permanent magnet with unmarked poles

stirrup

string

CAUTION: A MAGNET CAN DAMAGE A NON-DIGITAL WRIST WATCH. DO NOT BRING THE MAGNET NEAR YOUR WRIST WATCH.

Notes to the Teacher

S17A
III.2.c
2
4
101

A7
B3

*
-
*

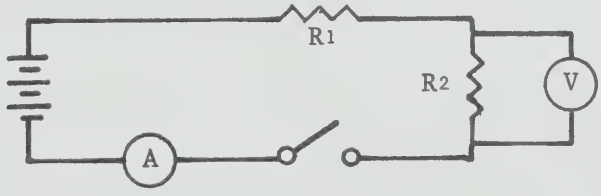
1. Provide the students with the circuit diagram.
2. Caution the students against closing the switch.
3. Consider using an inoperable source. Remove the fuse from the power supply to make it inoperable.
4. Evaluate the polarity and placement of the ammeter and voltmeter and the open switch.

LABORATORY-SKILL TEST INSTRUMENT 24

CONNECTING A CIRCUIT FROM A CIRCUIT DIAGRAM

Problem

Connect the circuit which corresponds to the circuit diagram shown.



Materials

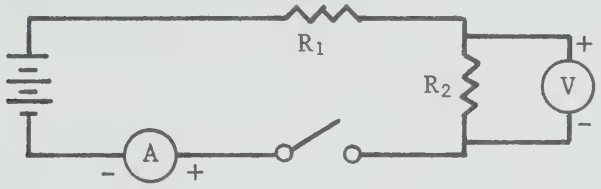
ammeter	2 resistors R_1 and R_2
connecting wires	switch
D. C. source	voltmeter

CAUTION: DO NOT CLOSE THE SWITCH.

Notes to the Teacher

S17A
III.2.c

1. Pre-wire the circuit as shown below.



2
4
101

A4
A7
A11

2. Make R_2 significantly different from R_1.
3. Do not close the switch.

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*

4. Consider using an inoperable source. Remove the fuse from the power supply to make it inoperable.

LABORATORY-SKILL TEST INSTRUMENT 25

DRAWING A CIRCUIT DIAGRAM

Problem

Draw a circuit diagram of the circuit. Indicate the polarity of the ammeter and voltmeter on the diagram.

Materials

ammeter	2 resistors R_1 and R_2
connecting wires	switch
D.C. source	voltmeter

CAUTION: DO NOT CLOSE THE SWITCH.

Notes to the Teacher

S17C
II.5.a
77
A7
A8
B3
C4
D3

1. Use a plane wave generator with a constant frequency.
2. Use dampers around the edges of the tank to minimize reflection.
3. Wax blocks form an ideal barrier. Lead strips can also be used.
4. Set up the ripple tank and vibrator to produce a clear standing wave pattern between the barrier and the generator and a travelling wave in the rest of the tank.

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LABORATORY-SKILL TEST INSTRUMENT 26

THE DISTANCE BETWEEN NODAL LINES

Problem

Measure both the wavelength of the travelling wave and the distance between the nodal lines in the standing wave pattern.

Materials

dampers	ripple tank and light source
hand stroboscope	screen
metre stick	straight barrier
periodic plane wave generator	wedges for levelling the tank

CAUTION: LIGHT BULBS COATED BLACK BECOME VERY HOT AND CAN IMPLODE IF THEY COME IN CONTACT WITH WATER.

LABORATORY-EXPERIMENT

TEST

INSTRUMENTS

LABORATORY-EXPERIMENT TEST INSTRUMENT 1

FREQUENCY OF A ROTATING DISC

Notes to the Teacher

S17C
I.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

S4

2. Minimum number of students: 2

A7
A8
B3
C4
D3

3. Prerequisite knowledge:

   a. number of open slits N

   b. object frequency f_o

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**
\-

   c. strobe frequency f_s

   d. $f_o = f_s N$ (image correctly frozen)

4. Preparation:

   a. Choose a rotating object whose frequency, once set, remains constant.

   b. Mark a spot near the circumference of a disc and attach it to the shaft of the rotating object.

   c. Adjust the frequency of the disc to about 5 Hz so that the image can be frozen using a hand stroboscope with two open slits.

5. CAUTION:

   DO NOT ASSIGN THIS EXPERIMENT TO A STUDENT PRONE TO EPILEPSY. FREQUENCIES CLOSE TO THE NATURAL BRAIN FREQUENCY (10 - 14 HZ) CAN TRIGGER AN EPILEPTIC SEIZURE.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 1

FREQUENCY OF A ROTATING DISC

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist working for a company which manufactures motors. You have been assigned the task of designing and implementing a method to determine the frequency of rotation of a disc attached to the shaft of a motor.

Materials

black tape
hand stroboscope
rotating disc attached to a motor with a constant frequency (e.g. electric drill
stop watch

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 1

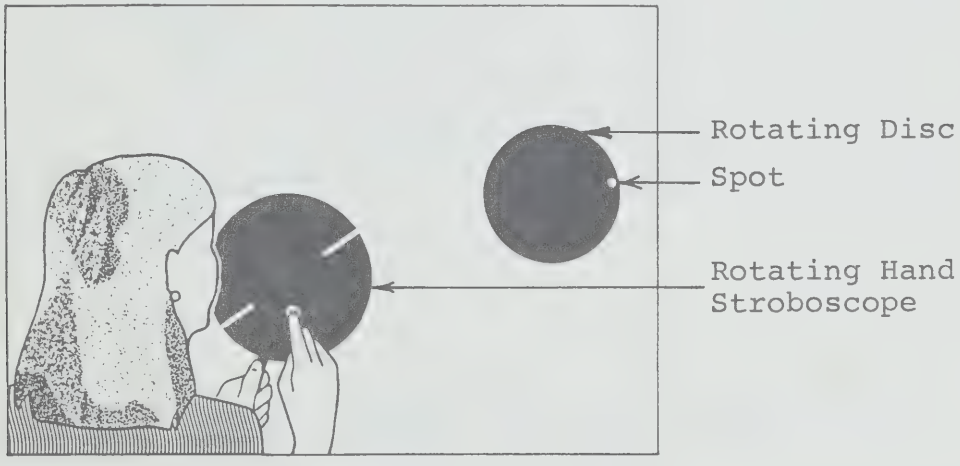
FREQUENCY OF A ROTATING DISC

Note: Return this sheet to your examiner at the end of the test.

Method

a. Close all but two slits on opposite sides of the hand stroboscope.

b. Hold the stroboscope in front of one eye and rotate it slowly while looking through the open slits at the rotating disc, as shown in the diagram.



c. Adjust the frequency of the hand stroboscope until the image of the spot marked on the circumference of the disc is correctly frozen in one position.

d. Measure and record the frequency of the hand stroboscope.

e. Calculate and record the frequency of the rotating disc. Show all calculations.

f. When you have finished, submit the procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 2

PERIOD OF A ROTATING DISC

Notes to the Teacher

S17C
I.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

S 4

2. Minimum number of students: 2

A7
A8
B3
C4
D3

3. Prerequisite knowledge:

   a. number of open slits N

   b. object frequency f_o

\-

   c. strobe frequency f_s

**
\-

   d. $f_o = f_s N$ (image correctly frozen)

   e. period T

   f. $T = \frac{1}{f}$

4. Preparation:

   a. Choose a rotating object whose period, once set, remains constant.

   b. Mark a spot near the circumference of a disc and attach it to the shaft of the rotating object.

   c. Adjust the frequency of the disc to about 5 Hz so that the image can be frozen using a hand stroboscope with two open slits.

5. CAUTION:

   DO NOT ASSIGN THIS EXPERIMENT TO A STUDENT PRONE TO EPILEPSY. FREQUENCIES CLOSE TO THE NATURAL BRAIN FREQUENCY (10 - 14 HZ) CAN TRIGGER AN EPILEPTIC SEIZURE.

LABORATORY-EXPERIMENT TEST INSTRUMENT 2

PERIOD OF A ROTATING DISC

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist working for a company which manufactures motors. You have been assigned the task of designing and implementing a method to determine the period of rotation of a disc attached to the shaft of a motor.

Materials

black tape
hand stroboscope
rotating disc attached to a motor with a constant period (e.g. electric drill)
stopwatch

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 2

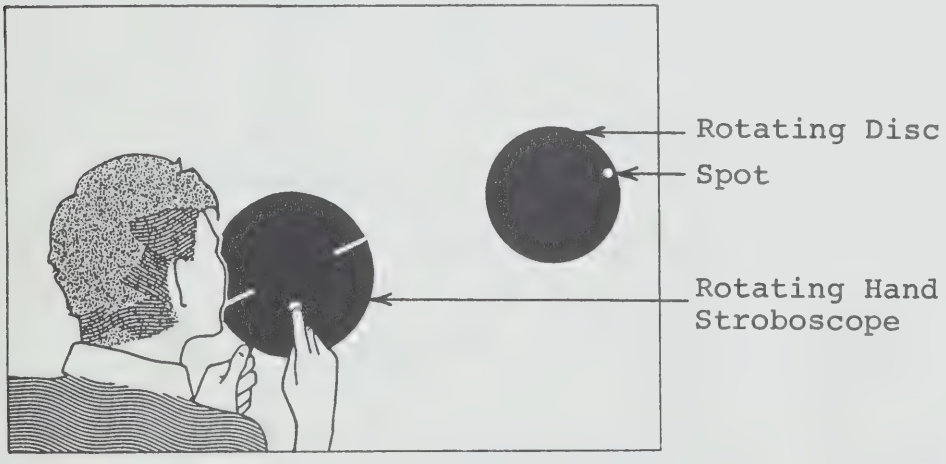
PERIOD OF A ROTATING DISC

Note: Return this sheet to your examiner at the end of the test.

Method

a. Close all but two slits on opposite sides of the hand stroboscope.

b. Hold the stroboscope in front of one eye and rotate it slowly while looking through the open slits at the rotating disc, as shown in the diagram.



c. Adjust the period of the hand stroboscope until the image of the spot marked on the circumference of the disc is correctly frozen in one position.

d. Measure and record the period of the hand stroboscope.

e. Calculate and record the period of the rotating disc. Show all calculations.

f. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 3

PERIOD OF A RECORDING TIMER

Notes to the Teacher

S17C
I.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

S 4

2. Minimum number of students: 1

A7
A8
B3
C4
D3

3. Prerequisite knowledge:

   a. hertz

   b. period

-
**

   c. recording timer

-

   d. tick

4. Preparation:

   a. Check that the recording timer has a constant frequency.

   b. If possible, use a timer with a frequency other than 60 Hz.

   c. Provide the student with 0.75 m of paper tape.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 3

PERIOD OF A RECORDING TIMER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist in the quality control section of a manufacturing firm. The firm has developed an electric recording timer. Your problem is to design and implement a method to determine the period of the recording timer.

Materials

carbon paper discs or
  self marking paper tape
connecting leads
marking pen
paper tape
power supply
recording timer
stopwatch
switch

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 3

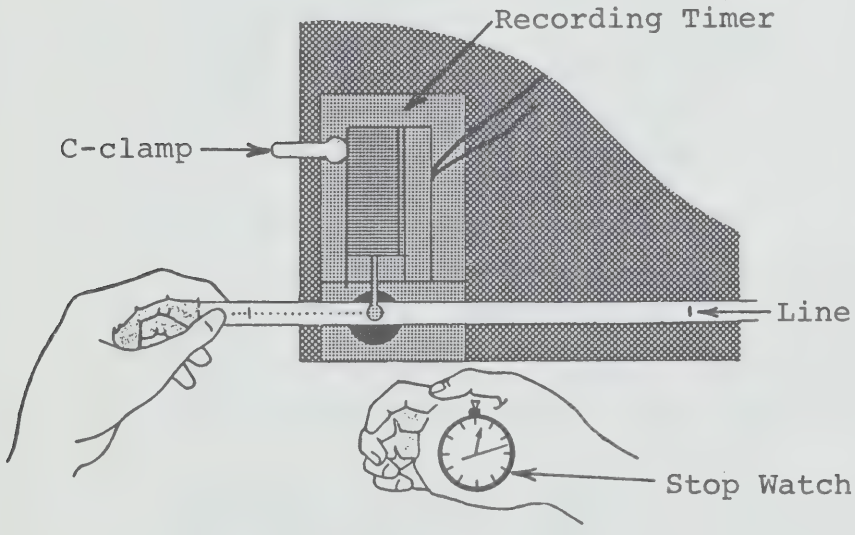
PERIOD OF A RECORDING TIMER

Note: Return this sheet to your examiner at the end of the test.

Method

a. Draw two lines across the paper tape, one near each end.

b. Start the recording timer and pull the paper tape at a uniform rate through the timer as shown in the diagram.



c. Record the time elapsed while the section of paper between the two lines passes through the timer.

d. Count the number of tick intervals marked by the recording timer between the two lines on the paper tape.

e. Calculate the period of the recording timer by using the elapsed time and the number of tick intervals.

f. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 4

ACCELERATION OF AN OBJECT USING A RECORDING TIMER

Notes to the Teacher

S17A
I.2.a
S17C
III.1.d

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (30 min)

2. Minimum number of students: 2

14
15
16
17

A7
C4
D3

3. Prerequisite knowledge:

   a. acceleration
   b. average velocity
   c. displacement
   d. inclined plane
   e. instantaneous velocity
   f. period
   g. position
   h. slope
   i. tangent

***
**
***

4. Preparation:

   a. Adjust the slope of the plane to yield a suitable acceleration. A slope of 20° to 30° works well.
   b. Provide the students with the period of the timer.
   c. Oil the bearings of the cart and clean the running surface.
   d. Two different procedure sheets have been provided: Method A uses tangents; Method B uses average velocities plotted at half time intervals.

LABORATORY-EXPERIMENT TEST INSTRUMENT 4

ACCELERATION OF AN OBJECT USING A RECORDING TIMER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist working for an engineering firm that designs dynamics carts. Your task is to determine the acceleration of a loaded dynamics cart that rolls down an inclined plane.

Materials

carbon paper discs or
  self marking paper tape
connecting leads
dynamics cart with load
graph paper
inclined plane
masking tape
metre stick
paper tape
power supply
recording timer
ruler
switch

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

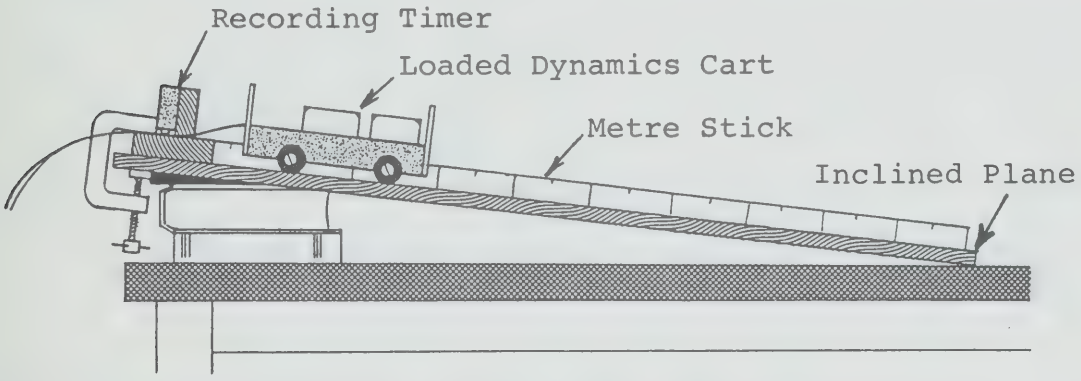
PROCEDURE SHEET 4

ACCELERATION OF AN OBJECT USING A RECORDING TIMER

Note: Return this sheet to the examiner at the end of the test.

Method A

a. Attach a length of paper tape to the cart. Thread the tape through the recording timer as shown.



b. Start the timer and release the cart down the inclined plane so that the paper tape is pulled through the timer.

c. Analyze the tape by marking the starting dot $t = 0$ and dividing the tape into equal time intervals (tocks) as shown on the tape.

d. Record the time in tocks and measure the position from the start corresponding to each tock.

e. Plot a graph of position versus time for the cart.

f. Determine the instantaneous velocity at several different times by drawing tangents to the position-time graph and calculating slopes.

g. Plot a graph of velocity versus time for the cart.

h. Calculate the average acceleration of the cart in $cm/tocks^2$ using the velocity-time graph.

i. Use the period provided by the examiner to calculate the acceleration of the cart in cm/s^2 if you have not already done so.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

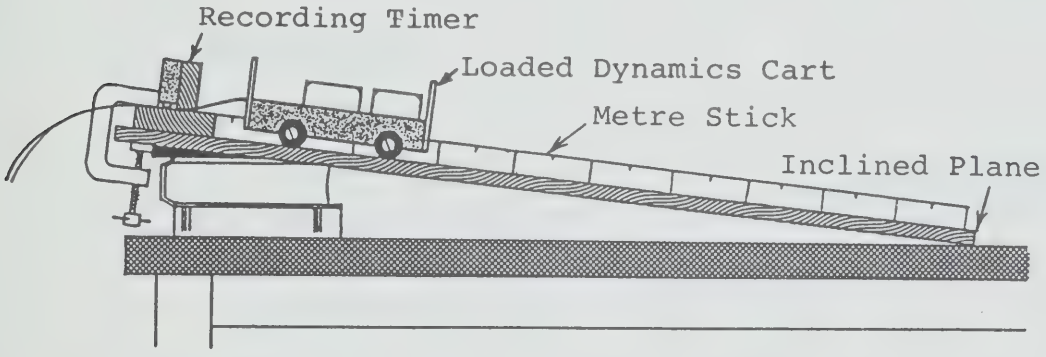
PROCEDURE SHEET 4

ACCELERATION OF AN OBJECT USING A RECORDING TIMER

Note: Return this sheet to the examiner at the end of the test.

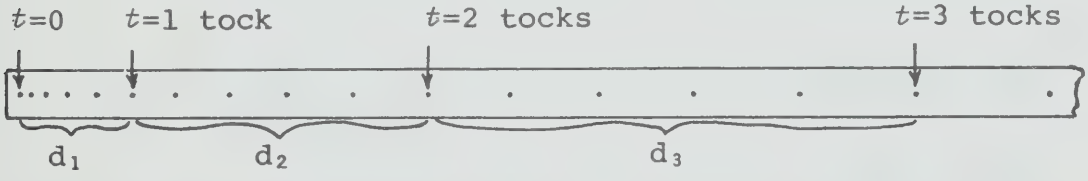
Method B

a. Attach a length of paper tape to the cart. Thread the tape through the recording timer as shown.



b. Start the timer and release the cart down the inclined plane so that the paper tape is pulled through the timer.

c. Analyze the tape by marking the starting dot $t = 0$ and dividing the tape into equal time intervals (tocks) as shown on the tape.



d. Measure the displacements (d_1, d_2, d_3, etc.) corresponding to each tock interval.

e. Calculate the average velocity for each tock interval by dividing the displacement by one tock.

f. Plot a graph of velocity versus time for the cart by plotting the average velocities at half tock intervals (0.5 tock, 1.5 tocks, etc.)

g. Calculate the average acceleration of the cart in cm/tock^2 using the velocity-time graph.

h. Use the period provided by the examiner to calculate the acceleration of the cart in cm/s^2 if you have not already done so.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 5

ACCELERATION OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

Notes to the Teacher

S17A
I.2.a
S17C
III.1.d

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (40 min)

2. Minimum number of students: 2

14
15
16
17

A7
C4
D3

3. Prerequisite knowledge:

   a. acceleration
   b. average acceleration
   c. instantaneous velocity
   d. magnification factor
   e. operation of the camera and photograph analysis
   f. period
   g. position
   h. slope

***
**
***

4. Preparation:

   a. Adjust the slope of the inclined plane to yield a suitable acceleration; a slope of 20°-30° works well.
   b. Preset the blinking light source or the light stroboscope so that a minimum of 15 images are recorded on the film.
   c. Give students the value for the period of the blinking light source and ensure that they do not readjust the frequency.
   d. Attach a soda straw to the cart as a marker if the blinking light source is not attached to the cart.
   e. Provide a pin and an overhead projector or a magnifying lens and a scale for analyzing the photograph. Teach students how to determine the magnification factor.
   f. Two different procedure sheets have been provided: Method A uses tangents; Method B uses average velocities plotted at half time intervals.

5. CAUTION:

   DO NOT ASSIGN THIS EXPERIMENT TO A STUDENT PRONE TO EPILEPSY. FREQUENCIES CLOSE TO THE NATURAL BRAIN FREQUENCY (10 - 14 HZ) CAN TRIGGER AN EPILEPTIC SEIZURE.

LABORATORY-EXPERIMENT TEST INSTRUMENT 5

ACCELERATION OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist working for an engineering firm that designs dynamics carts. Your task is to design and implement a method to determine the acceleration of a loaded dynamics cart that rolls down an inclined plane.

Materials

blinking light source
camera
dynamics cart with load
inclined plane
magnifying lens and scale, or overhead projector and pin
metre stick
metric ruler
pair of dividers

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 5

ACCELERATION OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

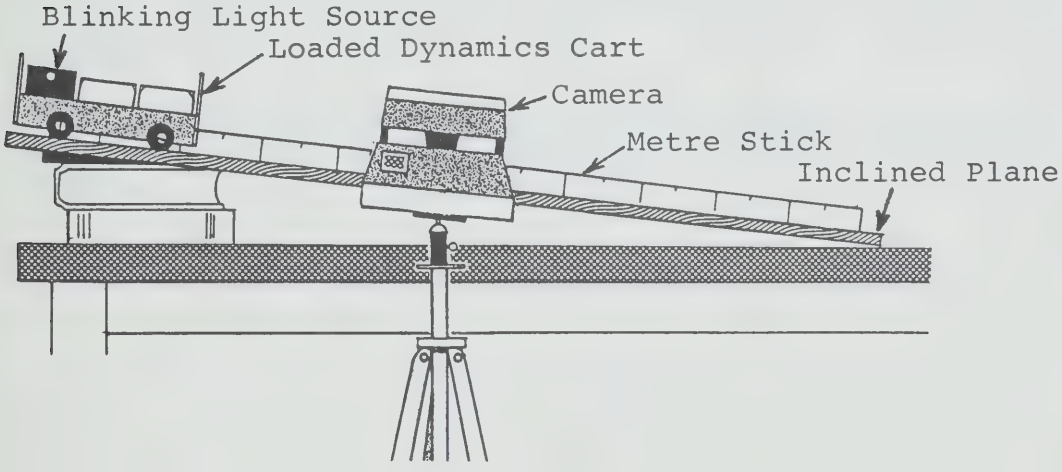
Note: Return this sheet to the examiner at the end of the test.

Method A

a. Position the camera at the same height as the cart and one to two metres from it.

b. Place a reference metre stick behind and parallel to the intended path of the cart.

c. Place a small blinking light source on the cart as shown in the diagram, or face a light stroboscope to shine on the cart and attach a marker to the cart.



d. Take a picture of the cart moving down the incline.

e. Analyze the photograph by marking the starting image $t = 0$ and dividing the photograph into equal time intervals (tocks) as shown.

ACCELERATION OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

Method A continued

f. Record the time in tocks and measure and record the position from the start corresponding to each tock. Take into consideration the magnification factor for the method used.

g. Plot a graph of position versus time for the cart.

h. Determine the instantaneous velocity at several different times by drawing tangents to the position-time graph and calculating slopes.

i. Plot a graph of velocity versus time for the cart.

j. Calculate the average acceleration of the cart in $cm/tocks^2$ using the velocity-time graph.

k. Use the period provided by the examiner to calculate the acceleration of the cart in cm/s^2 if you have not already done so.

l. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

PROCEDURE SHEET 5

ACCELERATION OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

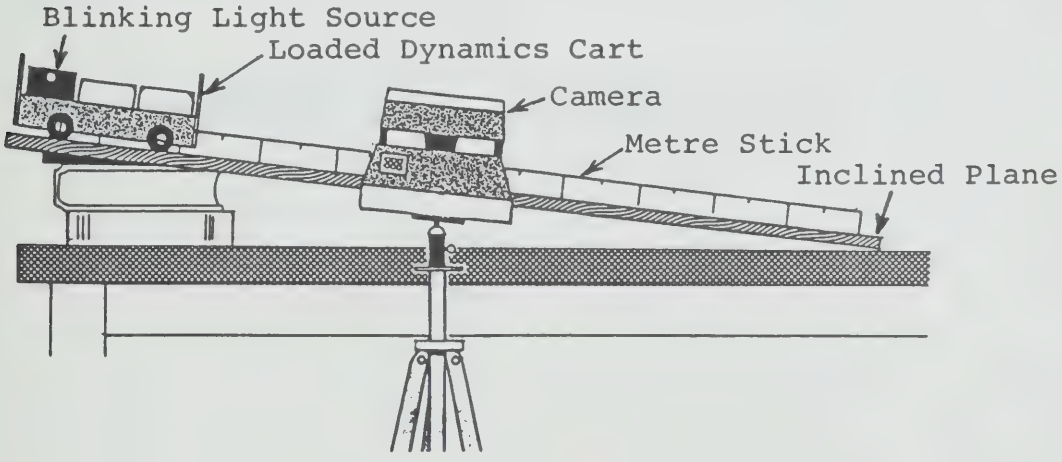
Note: Return this sheet to the examiner at the end of the test.

Method B

a. Position the camera at the same height as the cart and one to two metres from it.

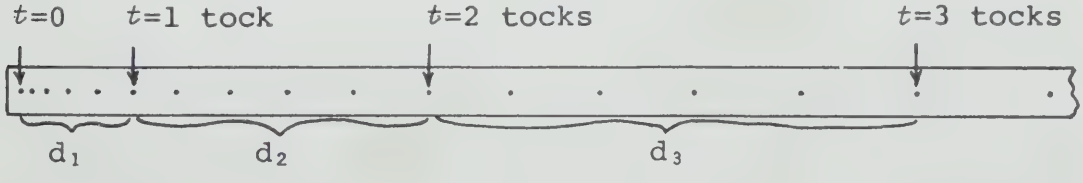
b. Place a reference metre stick behind and parallel to the intended path of the cart.

c. Place a small blinking light source on the cart as shown in the diagram, or face a light stroboscope to shine on the cart and attach a marker to the cart.



d. Take a picture of the cart moving down the incline.

e. Analyze the photograph by marking the starting image $t = 0$ and dividing the photograph into equal time intervals (tocks) as shown.



ACCELERATION OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

Method B continued

f. Measure the displacements d_1, d_2, d_3, etc. corresponding to each tock interval. Take into consideration the magnification factor for the method used.

g. Calculate the average velocity for each tock interval by dividing the displacement by one tock.

h. Plot a graph of velocity versus time for the cart by plotting the average velocities at half tock intervals (0.5 tock, 1.5 tocks, etc.)

i. Calculate the average acceleration of the cart in $cm/tock^2$ using the velocity-time graph.

j. Use the period provided by the examiner to calculate the acceleration of the cart in cm/s^2 if you have not already done so.

k. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 6

MASS OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

Notes to the Teacher

S17C
III.1.c

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (30 min)

35

2. Minimum number of students: 2

A8
A7
B3
C4
D3
-
**
-

3. Prerequisite knowledge:

   a. acceleration
   b. displacement
   c. force
   d. initial velocity
   e. magnification factor
   f. mass
   g. net/unbalanced
   h. Newton's second law
   i. operation of a camera
   j. period
   k. photograph analysis

4. Preparation:

   a. Adjust the slope of the surface to compensate for friction on the wheels.

   b. Provide the students with the period of the blinking light source.

   c. Adjust the mass of the loaded cart to the sensitivity of the spring scale provided.

5. CAUTION:

   DO NOT ASSIGN THIS EXPERIMENT TO A STUDENT PRONE TO EPILEPSY. FREQUENCIES CLOSE TO THE NATURAL BRAIN FREQUENCY (10 - 14 HZ) CAN TRIGGER AN EPILEPTIC SEIZURE.

LABORATORY-EXPERIMENT TEST INSTRUMENT 6

MASS OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Sometimes physicists use an indirect method to determine the size of an object or a physical quantity. Your problem is to design and implement a method to indirectly determine the mass of a loaded cart by studying its motion.

Materials

blinking light source
camera
dividers
metre stick
loaded dynamics cart of unknown mass
newton spring scale
thread
wedges

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 6

MASS OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

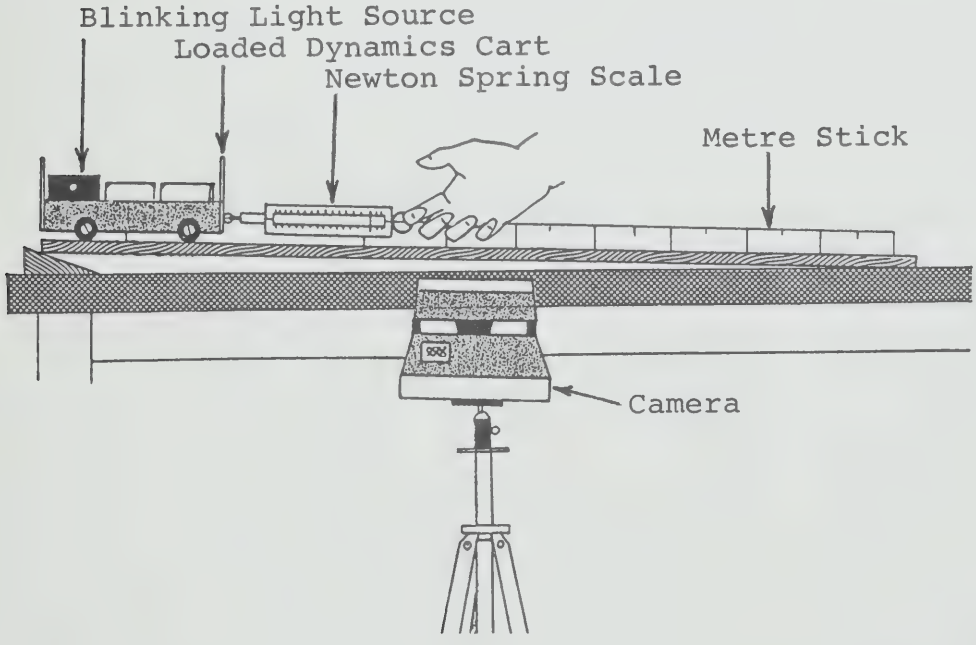
Note: Return this sheet to the examiner at the end of the test.

Method

a. Position the camera at the same height as the cart and one or two metres from it.

b. Place a reference metre stick behind and parallel to the intended path of the cart.

c. Place a small blinking light source on the cart as shown in the diagram, or face a light stroboscope to shine on the cart and attach a marker to the cart.



d. Use wedges to adjust the slope of the surface to compensate for the force of friction on the cart.

e. Activate the camera and use the spring scale to apply a small constant force to accelerate the loaded cart down the ramp. Record the applied force in newtons.

MASS OF AN OBJECT BY PHOTOGRAPHIC ANALYSIS

Method continued

f. Analyze the photograph to find the displacement of the cart in a specific time interval starting from rest. Take into consideration the magnification factor.

g. Use the relationship among acceleration, displacement, initial velocity and time to calculate the acceleration of the cart. Show all calculations.

h. Use the relationship among acceleration, net force, and mass to calculate the mass of the loaded cart. Show all calculations.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 7

MASS OF AN OBJECT USING A RECORDING TIMER

Notes to the Teacher

S17C
III.1.c

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (30 min)

35

2. Minimum number of students: 2

A8
A7
B3
C4
D3

3. Prerequisite knowledge:

   a. acceleration
   b. displacement
   c. force
   d. friction
   e. initial velocity
   f. mass
   g. net/unbalanced
   h. Newton's second law
   i. period

-
*
-

4. Preparation:

   a. Adjust the slope of the surface to compensate for friction from the recording timer and the wheels of the cart.

   b. Provide students with the frequency of the timer.

   c. Adjust the mass of the loaded cart to the sensitivity of the scale provided.

LABORATORY-EXPERIMENT TEST INSTRUMENT 7

MASS OF AN OBJECT USING A RECORDING TIMER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Sometimes physicists use an indirect method to determine the size of an object or a physical quantity. Your problem is to design and implement a method to indirectly determine the mass of a cart and load by studying its motion.

Materials

loaded dynamics cart of unknown mass
long ramp
masking tape
metre stick
newton spring scale
paper tape
power supply
recording timer
thread
wedges

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 7

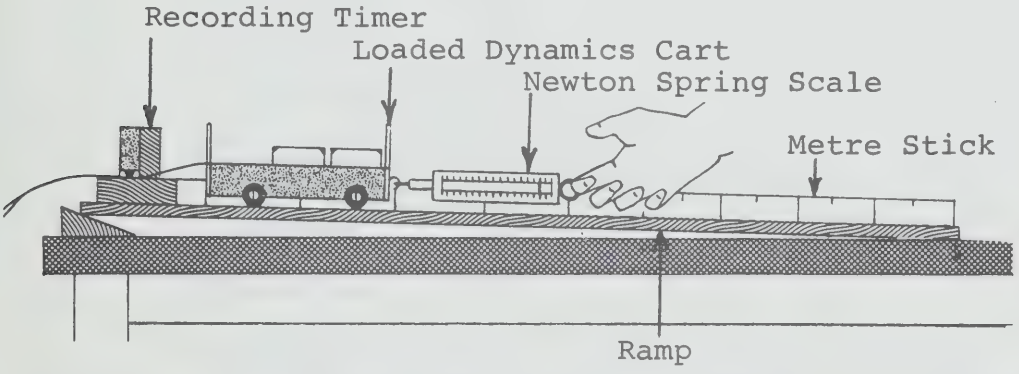
MASS OF AN OBJECT USING A RECORDING TIMER

Note: Return this sheet to the examiner at the end of the test.

Method

a. Thread a one metre length of paper tape through the recording timer and attach it to the cart.

b. Start the timer and use wedges to adjust the slope of the ramp to compensate for friction, as shown.



c. Repeat step a. Start the recording timer, and use the spring scale to apply a small constant force to accelerate the loaded cart down the ramp. Record the applied force in newtons.

d. Analyze the paper tape to find the displacement of the cart in a specific time interval starting from rest.

e. Use the relationship among acceleration, displacement, initial velocity and time to calculate the acceleration of the cart. Show all calculations.

f. Use the relationship among acceleration, net force and mass to calculate the mass of the loaded cart. Show all calculations.

g. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 8

FORCE CONSTANT OF A SPRING

Notes to the Teacher

S17A
I.2.b
S17C
III.6.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (25 min)
2. Minimum number of students: 1

SS 57

3. Prerequisite knowledge:

A2
A7

   a. extension

B3
D1

   b. force

D3

   c. force constant

**

   d. Hooke's Law

**
-

   e. slope

4. Preparation:

   Provide an assortment of masses having a total mass within the elastic limit of the spring.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 8

FORCE CONSTANT OF A SPRING

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Spring manufacturers specify the force constant of springs sold to science supply companies. Imagine that you work for the spring manufacturer. Your task is to design and implement a method to determine the force constant of the spring.

Materials

adjustable clamp
C-clamp
graph paper
metre stick
retort stand
ring stand
spring
standard masses

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 8

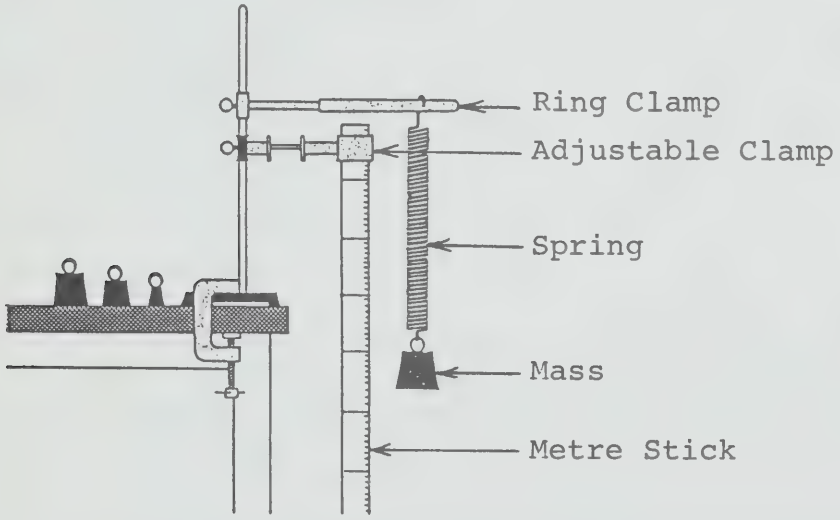
FORCE CONSTANT OF A SPRING

Note: Return this sheet to the examiner at the end of the test.

Method

a. Clamp the retort stand to the edge of the table using the C-clamp.

b. Suspend the spring over the edge of the table from the ring clamp, as shown in the diagram.



c. Position the metre stick in an upright position beside the spring using the adjustable clamp.

d. Record the unstretched position of the bottom of the spring.

e. Hang masses in steps from the lower end of the spring.

f. After the addition of each mass, record both the total extension of the spring and the total mass attached.

g. Calculate the force of gravity acting on each mass in newtons. (g = 9.8 N/kg)

h. Plot a graph of force against extension.

i. Use the graph to determine the force constant of the spring. Show all calculations.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 9

ANGLE OF MINIMUM DEVIATION USING A PRISM AND PINS

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (30 min)

60

2. Minimum number of students: 1

A2
A7
B3
C4
D3

3. Prerequisite knowledge:

   a. angle of minimum deviation

   b. emergent ray

*
-
*

   c. graphing

   d. incident ray

   e. refracted ray

4. Preparation:

   a. An equilateral triangular prism provides good results.

   b. Several stations can be set up around the room.

   c. Use glass, plastic, or water prisms.

   d. Prisms to hold water can be constructed using plexiglass and silicone glue.

   e. Try the experiment ahead of time to determine the expected result.

LABORATORY-EXPERIMENT TEST INSTRUMENT 9

ANGLE OF MINIMUM DEVIATION USING A PRISM AND PINS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you work as a physicist in the optics department of a prism manufacturing firm. Your firm has developed a new prism. Your problem is to design and implement a method to determine the angle of minimum deviation for a particular pair of faces of this prism.

Materials

graph paper
4 pins
prism
protractor
ruler
5 sheets of paper
tack board

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 9

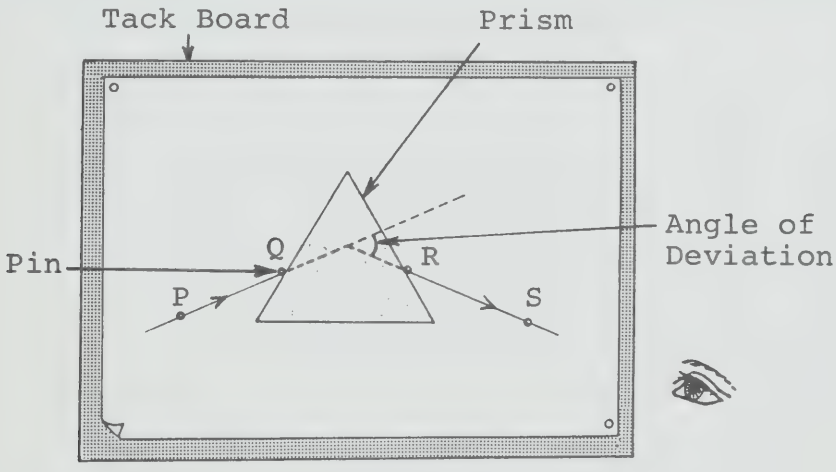
ANGLE OF MINIMUM DEVIATION USING A PRISM AND PINS

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the prism on the sheet of paper on the tack board. With a pencil, trace around the edges of the prism.

b. Stick a pin Q upright in the paper so that it touches one edge of the prism as shown in the diagram.



c. Stick another pin P upright in the paper several centimetres from pin Q so that the line joining PQ meets the edge of the prism at an oblique angle.

d. Look through the prism from the opposite side and line up the images of pins P and Q.

e. Insert two pins R and S several centimetres apart on this side of the prism with pin R touching the edge of the prism. The images of P and Q should appear in a straight line with R and S.

f. Mark the position of each pin, remove the pins, and join PQ, QR and RS.

g. Extend the lines representing the incident and emergent rays to form the angle of deviation.

ANGLE OF MINIMUM DEVIATION USING A PRISM AND PINS

Method continued

h. Measure and record the angle of deviation.

i. Repeat steps a to h at least four more times using a different angle of incidence each time.

j. Plot a graph of the angle of incidence against the angle of deviation. From the graph, determine the angle of minimum deviation.

k. When you have finished, submit this procedure sheet, the experiment diagram sheets, the graph, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 10

ANGLE OF MINIMUM DEVIATION USING A PRISM AND A RAY BOX

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (25 min)

60

2. Minimum number of students: 1

A2
A7
B3
C4
D3

3. Prerequisite knowledge:

   a. angle of minimum deviation

   b. emergent ray

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-
*

   c. incident ray

   d. refracted ray

4. Preparation:

   a. An equilateral triangular prism provides good results.

   b. Several stations can be set up around the room.

   c. Use glass, plastic, or water prisms.

   d. Prisms to hold water can be constructed using plexiglass and silicone glue.

   e. Try the experiment ahead of time to determine the expected result.

   f. To achieve better results, place a red filter in front of the ray box to produce a near monochromatic light source.

LABORATORY-EXPERIMENT TEST INSTRUMENT 10

ANGLE OF MINIMUM DEVIATION USING A PRISM AND A RAY BOX

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you work as a physicist in the optics department of a prism manufacturing firm. Your firm has developed a new prism. Your problem is to design and implement a method to determine the angle of minimum deviation for a particular pair of faces of this prism.

Materials

prism
protractor
ray box
red filter
ruler
sheet of white paper
slit aperture

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 10

ANGLE OF MINIMUM DEVIATION USING A PRISM AND A RAY BOX

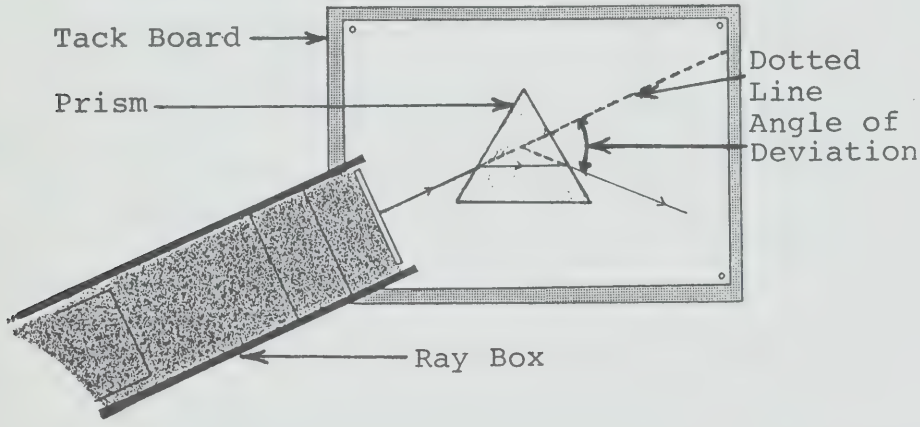
Note: Return this sheet to your examiner at the end of the test.

Method

a. Draw a dotted line diagonally across the sheet of paper.

b. Direct a single ray of light along the dotted line.

c. Place the prism on the paper so that the ray of light hits one edge of the prism at an oblique angle as shown in the diagram.



d. Without moving the ray box, slowly rotate the prism first clockwise, and then counterclockwise to find the position where the ray of light is deviated the least from its original path.

e. When this position is located, mark the paths of the incident and emergent rays.

f. With a pencil, trace around the edges of the prism.

g. Remove the prism.

h. Extend the line representing the emergent ray to form the angle of deviation shown in the diagram.

i. Measure and record the angle of minimum deviation.

j. Repeat steps a to i several times and average the results.

k. When you have finished, submit this procedure sheet, the diagrams, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 11

INDEX OF REFRACTION OF A SOLID USING A RAY BOX

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

65
279

3. Prerequisite knowledge:

A8
B4
C4
D3

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*
**

a.	emergent ray	f.	point of incidence
b.	incident ray	g.	ray
c.	index of refraction	h.	refracted ray
d.	normal	i.	refraction
e.	oblique	j.	transparent

4. Preparation:

   a. Use either transparent plastic or glass.

   b. Decide in advance whether a calculator with trigonometric functions may be used.

LABORATORY-EXPERIMENT TEST INSTRUMENT 11

INDEX OF REFRACTION OF A SOLID USING A RAY BOX

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist in the research and development centre of a manufacturing firm. The firm has made a new transparent material. You have been asked to determine the index of refraction of the material.

Materials

pencil
protractor
ray box
rectangular transparent sample
ruler
sheet of paper
sine tables
slit aperture

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 11

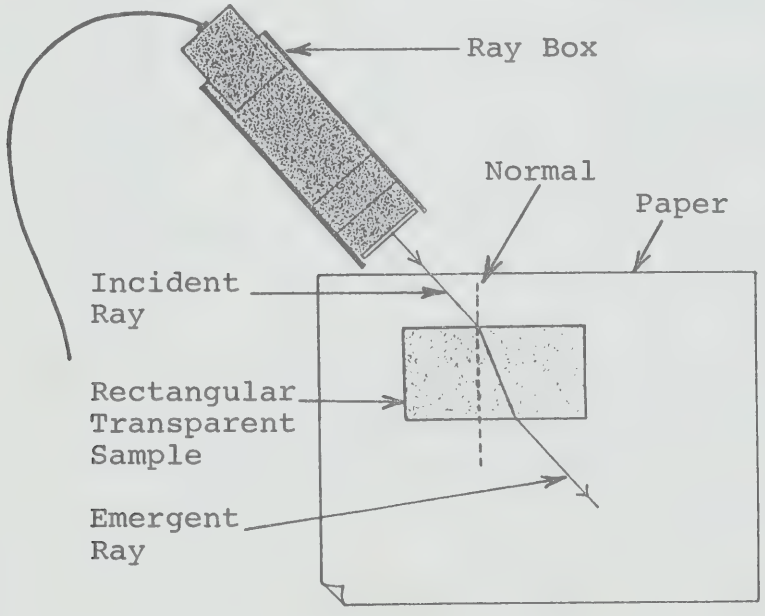
INDEX OF REFRACTION OF A SOLID USING A RAY BOX

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the rectangular transparent sample on the sheet of paper. With a pencil trace around the edges of the sample.

b. Direct a single ray of light at an oblique angle toward one edge of the sample as shown in the diagram.



c. Mark the path of the incident and emergent rays.

d. Remove the transparent sample and draw the path of the refracted ray.

e. Draw the normal at the point of incidence.

f. Measure and record the angle of incidence and the angle of refraction.

g. Determine the index of refraction of the sample. Show all calculations.

h. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 12

INDEX OF REFRACTION OF A SOLID USING PINS

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

65
279

3. Prerequisite knowledge:

A8
B4
C4
D3

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*
**

a. emergent ray
b. incident ray
c. index of refraction
d. normal
e. oblique angle
f. point of incidence
g. ray
h. refracted ray
i. refraction
j. transparent

4. Preparation:

   a. Use either transparent plastic or glass.

   b. Decide in advance whether a calculator with trigonometric functions may be used.

LABORATORY-EXPERIMENT TEST INSTRUMENT 12

INDEX OF REFRACTION OF A SOLID USING PINS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist in the research and development centre of a manufacturing firm. The firm has made a new type of transparent solid. You have been asked to determine the index of refraction of the solid.

Materials

pencil
protractor
rectangular transparent sample
ruler
sheet of paper
sine tables
4 straight pins
tack board

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 12

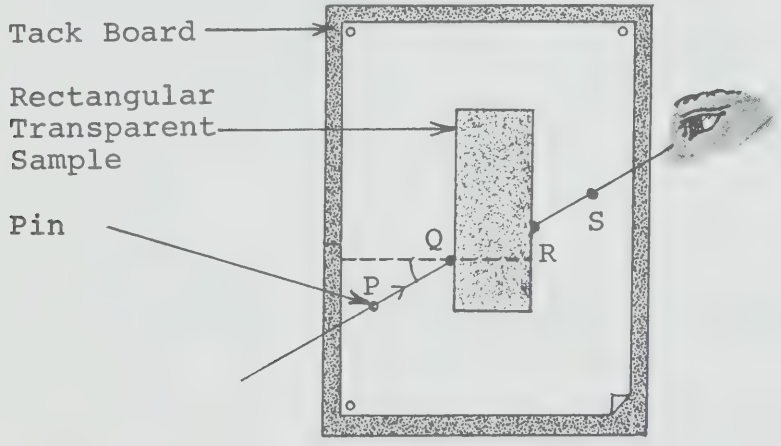
INDEX OF REFRACTION OF A SOLID USING PINS

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the rectangular transparent sample on the sheet of paper. Outline the edges of the sample with a pencil.

b. Stick a pin Q upright in the paper so that it touches one long edge of the sample as shown in the diagram.



c. Stick another pin P upright in the paper several centimetres from pin Q so that the line joining PQ meets the edge of the sample at an oblique angle.

d. Look through the sample from the opposite side and line up the images of pins P and Q.

e. Insert two pins R and S several centimetres apart on the viewing side of the sample with pin R touching the edge of the sample. The images of P and Q, as seen through the block, must be in a straight line with pins R and S.

f. Mark the position of each pin, remove the pins and sample, and join PQ, QR, and RS.

g. Draw the normal at the point of incidence.

h. Measure and record the angles of incidence and refraction.

i. Determine the index of refraction of the sample. Show all calculations.

j. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 13

INDEX OF REFRACTION OF A LIQUID USING A RAY BOX

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

65
279

3. Prerequisite knowledge:

A8
B4
C4
D3

a.	angle of incidence	e.	oblique angle
b.	angle of refraction	f.	polar co-ordinate paper
c.	index of refraction	g.	refraction
d.	normal	h.	sine

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*
**

4. Preparation:

   a. Do not use carbon tetrachloride, carbon disulphide, turpentine, acids, bases, or methyl alcohol.

   b. Satisfactory liquids are water, cooking oil, ethylene glycol, glycerine, and a concentrated sugar solution.

   c. Make a vertical scratch part way down at the centre of the flat side of the dish.

   d. It is difficult to clean the containers after the use of oils.

LABORATORY-EXPERIMENT TEST INSTRUMENT 13

INDEX OF REFRACTION OF A LIQUID USING A RAY BOX

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist in a forensic science laboratory. The police have just brought you a sample of an unknown liquid. You are to help identify the liquid by determining its index of refraction.

Materials

pencil
polar co-ordinate paper
ray box
ruler
semi-circular plastic container
single slit aperture
sine tables
transparent liquid

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 13

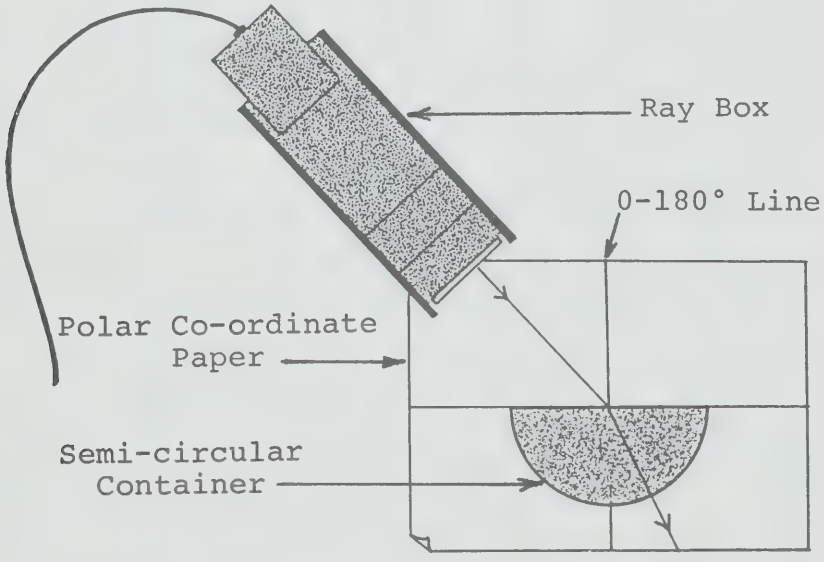
INDEX OF REFRACTION OF A LIQUID USING A RAY BOX

Note: Return this sheet to your examiner at the end of the test.

Method

a. Half fill the semi-circular plastic container with the unknown liquid.

b. Place the container on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the centre (scratch) of the flat surface as shown in the diagram. The flat surface should be along the 90-270° line.



c. Direct a single ray of light at an oblique angle toward the scratch.

d. Record the angle of incidence and the angle of refraction.

e. Determine the index of refraction for the liquid. Show all calculations.

f. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 14

INDEX OF REFRACTION OF A LIQUID USING PINS

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

65
279

3. Prerequisite knowledge:

A8
B8
C4
D3

a. angle of incidence
b. angle of refraction
c. index of refraction
d. normal
e. oblique angle
f. polar co-ordinate paper
g. refraction
h. sine

**
*
**

4. Preparation:

   a. Do not use carbon tetrachloride, carbon disulphide, turpentine, acids, bases or methyl alcohol.

   b. Satisfactory liquids are water, cooking oil, ethylene glycol, glycerine, and a concentrated sugar solution.

   c. Make a vertical scratch at the centre of the flat side of the dish.

   d. It is difficult to clean the containers after the use of oils.

LABORATORY-EXPERIMENT TEST INSTRUMENT 14

INDEX OF REFRACTION OF A LIQUID USING PINS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist in the research and development centre of a large firm. A field worker has just brought you a sample of an unknown liquid. You are to determine the index of refraction of the liquid.

Materials

liquid
pencil
polar co-ordinate paper
ruler
semi-circular plastic container
sheet of paper
sine tables
straight pins
tack board

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 14

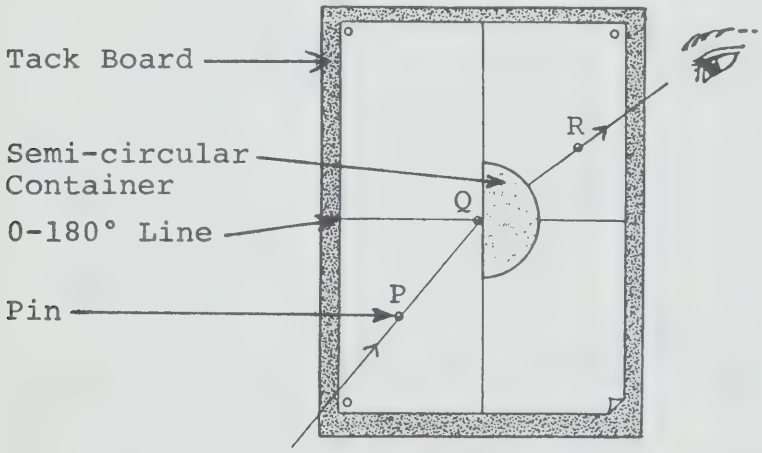
INDEX OF REFRACTION OF A LIQUID USING PINS

Note: Return this sheet to your examiner at the end of the test.

Method

a. Half fill the semi-circular plastic container with the unknown liquid.

b. Place the container on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the centre (scratch) of the flat surface as shown in the diagram. The flat surface should be along the 90-270° line.



c. Label the scratch Q.

d. Stick a pin P upright in the paper several centimetres from Q so that the line joining PQ meets the edge of the container at an oblique angle.

e. Look through the container from the curved side and line up the images of pins P and Q as viewed through the liquid.

f. Insert a pin R several centimetres from the curved side of the container so that it is in line with the images of P and Q as seen through the liquid.

g. Mark the position of each pin, remove the pins and container, and join PQ and QR.

h. Measure and record the angles of incidence and refraction.

i. Determine the index of refraction. Show all calculations.

j. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 15

LENGTH OF A PENDULUM HAVING A SPECIFIC PERIOD

Notes to the Teacher

S17A
I.1.b
S17C
I.1.a

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (25 min)

2. Minimum number of students: 1

S 69

3. Prerequisite knowledge:

A2
C4
B5

   a. acceleration due to gravity

   b. centre of mass

**

   c. frequency

*

**

   d. period

   e. vibration

4. Preparation:

   a. The length of the pendulum should be measured to the centre of mass of the bob.

   b. To choose specific periods, use the formula $T = 2\pi\sqrt{\frac{l}{g}}$ where l is the length in metres, T the period in seconds, and g the force of gravity to mass ratio in newtons per kilogram. (g = 9.8 N/kg)

   c. Several stations can be set up around the room, each station being given a different period.

   d. Use a rubber stopper, split longitudinally half way across, and an adjustable clamp as the pendulum support. The length of the pendulum can be easily adjusted by loosening the clamp and pulling the string through the split in the stopper.

   e. Write the specified period in the space provided at the end of the problem statement in the Laboratory-Experiment Test Instrument.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 15

LENGTH OF A PENDULUM HAVING A SPECIFIC PERIOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for a company that manufactures pendulum clocks. A clock has been returned because of inaccuracy in time keeping. Your task is to determine the length of a pendulum needed to yield a period of ___ s.

Materials

adjustable clamp
C-clamp
half-split stopper
metre stick
retort stand
stopwatch
string pendulum

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

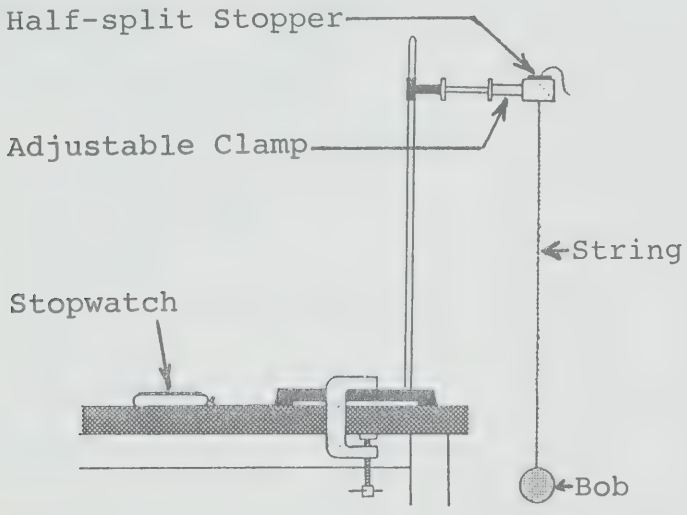
PROCEDURE SHEET 15

LENGTH OF A PENDULUM HAVING A SPECIFIC PERIOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Attach the adjustable clamp near the top of the retort stand as shown in the diagram.



b. Insert the half-split stopper between the jaws of the adjustable clamp.

c. Suspend the pendulum from the stopper by passing the string through the slit and tightening the clamp.

d. Start the pendulum swinging with a small amplitude.

e. Find the period of the pendulum by measuring the time for ten complete vibrations and determining the time for one complete vibration.

f. Adjust the length of the pendulum by pulling the string through the stopper.

g. Repeat steps e and f until the specified period is obtained.

h. Measure and record the length of the pendulum which produced this period. Measure the length from the bottom of the stopper to the centre of mass of the bob.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 16

LENGTH OF A PENDULUM HAVING A SPECIFIC FREQUENCY

Notes to the Teacher

S17A
I.1.b
S17C
I.1.a

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (25 min)
2. Minimum number of students: 1

S 69

3. Prerequisite knowledge:

A2
C4
B5

   a. acceleration due to gravity

   b. centre of mass

**
*
**

   c. frequency

   d. period

   e. vibration

4. Preparation:

   a. The length of the pendulum should be measured to the centre of mass of the bob.

   b. To choose specific frequencies, use the formula $f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$ where l is the length in metres, f the frequency in hertz, and g the force of gravity to mass ratio in newtons per kilogram. (g = 9.8 N/kg)

   c. Several stations can be set up around the room, each station being given a different frequency.

   d. Use a rubber stopper, split longitudinally half way across, and an adjustable clamp as the pendulum support. The length of the pendulum can be easily adjusted by loosening the clamp and pulling the string through the split in the stopper.

   e. Record the specified frequency in the space provided at the end of the problem statement in the Laboratory-Experiment Test Instrument.

LABORATORY-EXPERIMENT TEST INSTRUMENT 16

LENGTH OF A PENDULUM HAVING A SPECIFIC FREQUENCY

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for a company that manufactures pendulum clocks. A clock has been returned because of inaccuracy in time keeping. Your task is to determine the length of a pendulum needed to yield a frequency of ____ Hz.

Materials

adjustable clamp
C-clamp
metre stick
retort stand
split stopper
stopwatch
string pendulum

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

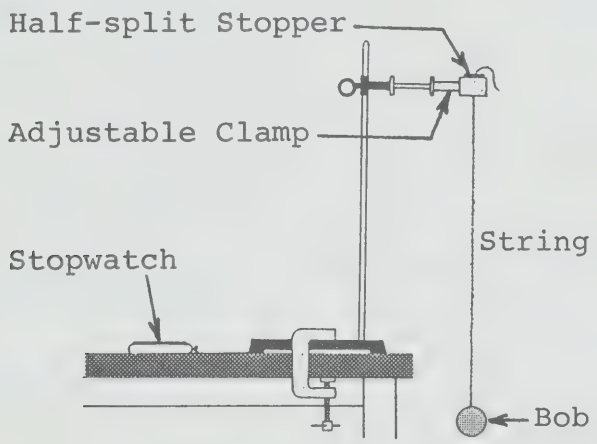
PROCEDURE SHEET 16

LENGTH OF A PENDULUM HAVING A SPECIFIC FREQUENCY

Note: Return this sheet to your examiner at the end of the test.

Method

a. Attach the adjustable clamp near the top of the retort stand as shown in the diagram.



b. Insert the half-split stopper between the jaws of the adjustable clamp.

c. Suspend the pendulum from the stopper by passing the string through the slit and tightening the clamp.

d. Start the pendulum swinging with a small amplitude.

e. Find the frequency of the pendulum by measuring the time for ten complete vibrations and determining the number of vibrations in one second.

f. Adjust the length of the pendulum by pulling the string through the stopper.

g. Repeat steps e and f until the specific frequency is obtained.

h. Measure and record the length of the pendulum which produces this frequency. Measure the length from the bottom of the split stopper to the centre of mass of the bob.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 17

ANGLES OF INCIDENCE AND REFLECTION OF WATER WAVES

Notes to the Teacher

S17C
II.4.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

71

2. Minimum number of students: 2

A2
B3

3. Prerequisite knowledge:

   a. angle of incidence
   b. angle of reflection
   c. angles between the wave fronts and the barrier
   d. normal
   e. plane waves
   f. reflection
   g. wave front

4. Preparation:

   a. Specify an angle of incidence other than 45° to prevent the student from getting the correct answer using an incorrect procedure.

   b. Record the specified angle in the space provided in the problem statement in the Laboratory-Experiment Test Instrument.

   c. Set up a ripple tank and accessories ahead of time to decrease the time needed for the experiment.

5. CAUTION:

   LIGHT BULBS COATED BLACK BECOME VERY HOT AND CAN IMPLODE IF THEY COME IN CONTACT WITH WATER.

LABORATORY-EXPERIMENT TEST INSTRUMENT 17

ANGLES OF INCIDENCE AND REFLECTION OF WATER WAVES

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Direct plane water waves at an angle of incidence of ____° toward a straight, reflecting barrier. Measure the angle of reflection of the water waves. Draw a diagram to show the barrier and an incident and reflected wave front. Label the direction of travel of the wave fronts and the angles of incidence and reflection.

Materials

dampers
metre stick
paper screen
periodic plane wave generator
protractor
ripple tank with light source
straight barrier
wedges for levelling tank

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

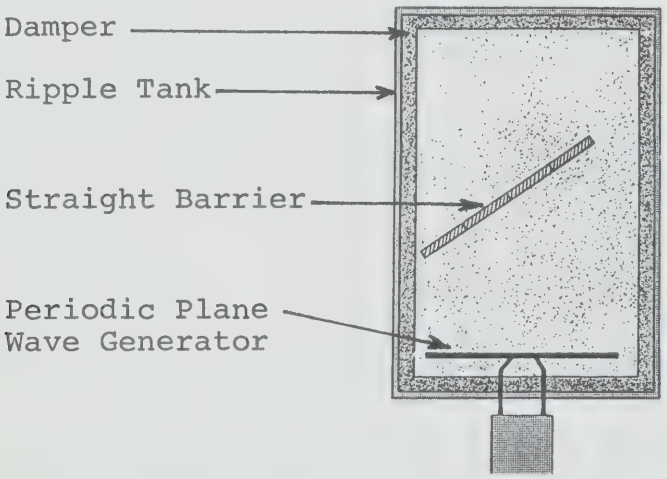
PROCEDURE SHEET 17

ANGLES OF INCIDENCE AND REFLECTION OF WATER WAVES

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the straight barrier at an angle to the periodic plane wave generator, as shown in the diagram.



b. Adjust the light source above the tank to obtain a sharp image on the paper screen below the tank.

c. Direct plane waves of constant frequency toward the straight barrier.

d. Adjust the barrier so that the plane waves are incident on the barrier at the specified angle of incidence.

e. Measure the angle of reflection of the water waves on the screen as accurately as possible.

f. Draw a diagram to show the barrier and an incident and reflected wave front. Label the direction of travel of the wave fronts and the angles of incidence and reflection.

g. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 18

REFRACTION OF WATER WAVES AT AN INTERFACE

Notes to the Teacher

S17C
II.4.c

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (25 min)

72

2. Minimum number of students: 2

A7
B3

3. Prerequisite knowledge:

-
*
-

   a. angle of incidence

   b. angle of refraction

   c. angles between the wave fronts and the interface

   d. normal

4. Preparation:

   a. If a hand stroboscope is used, two students are required for the exercise.

   b. Specify an angle of incidence other than 45° to prevent students from getting the correct set up using an incorrect procedure.

   c. Record the specified angle in the space provided in the problem statement in the Laboratory-Experiment Test Instrument.

   d. Use a constant frequency plane wave generator.

   e. Use dampers to minimize undesirable reflection.

   f. The layer of water over the refraction plate must be very thin and the tank level for best results.

   g. Set up the ripple tank and accessories ahead of time to decrease the time needed for the experiment.

5. CAUTION:

   LIGHT BULBS COATED BLACK BECOME VERY HOT AND CAN IMPLODE IF THEY COME IN CONTACT WITH WATER.

LABORATORY-EXPERIMENT TEST INSTRUMENT 18

REFRACTION OF WATER WAVES AT AN INTERFACE

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Direct plane water waves at an angle of incidence of ____° toward the interface between deep and shallow water. Measure the angle of refraction of the water waves. Draw a labelled diagram showing the deep and shallow water regions, and an incident and a refracted wave front. Label the direction of travel of the wave fronts and the angle of incidence and the angle of refraction.

Materials

dampers
hand stroboscope
metre stick
paper screen
periodic plane wave generator
protractor
ripple tank and light source
straight barriers
transparent refraction plate
two metric rulers
wedges for levelling tank

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

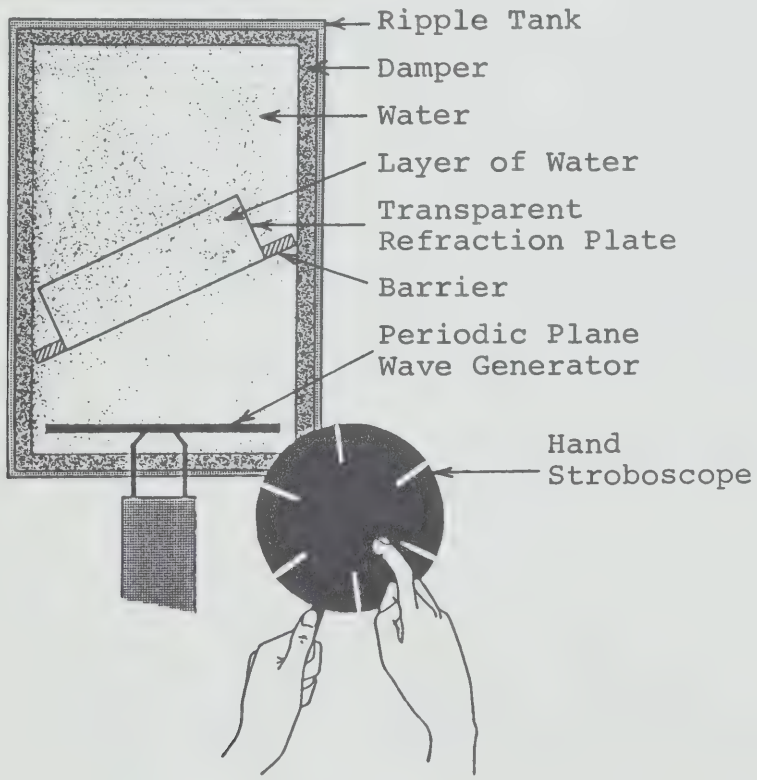
PROCEDURE SHEET 18

REFRACTION OF WATER WAVES AT AN INTERFACE

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the periodic plane wave generator near the refraction plate as shown in the diagram.



b. Direct plane periodic waves toward the near edge of the refraction plate. View the periodic waves through the hand stroboscope and "freeze" the waves by turning the stroboscope at the appropriate frequency.

c. Adjust the refraction plate so that the plane water waves are incident on the interface between deep and shallow water at the specified angle of incidence.

d. Measure and record the angle of refraction of the water waves in the shallow water.

Method continued

e. Draw a diagram to show the deep and shallow water regions and an incident and refracted wave front. Label the direction of travel of the wave fronts, and the angle of incidence and the angle of refraction.

f. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 19

CRITICAL ANGLE FOR A LIQUID USING PINS: DIRECT METHOD

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (30 min)

2. Minimum number of students: 1

82
287

3. Prerequisite knowledge:

A2
A7
B3
C4

   a. angle of incidence
   b. angle of refraction
   c. critical angle
   d. normal
   e. oblique angle
   f. polar co-ordinate paper

**
*
**

4. Preparation:

   a. Do not use carbon tetrachloride, carbon disulphide, turpentine, acids, bases, or methyl alcohol.

   b. Satisfactory liquids are water, cooking oil, ethylene glycol, glycerine, and a concentrated sugar solution.

   c. Make a fine vertical scratch half way down at the centre of the flat surface of the semi-circular dish using a pin or a needle.

   d. It is difficult to clean the container after the use of oils.

   e. This method involves increasing the angle of incidence gradually until the critical angle is reached and measuring it directly. No tables of trigonometric functions are provided to prevent students from determining the refractive index and calculating the critical angle.

LABORATORY-EXPERIMENT TEST INSTRUMENT 19

CRITICAL ANGLE FOR A LIQUID USING PINS: DIRECT METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist working in the research and development centre of a manufacturing firm. The firm has made a new transparent liquid. You have been asked to determine the critical angle of a sample of the liquid without determining the refractive index.

Materials

pencil
polar co-ordinate paper
ruler
semi-circular plastic container
straight pins
tack board
transparent liquid sample

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 19

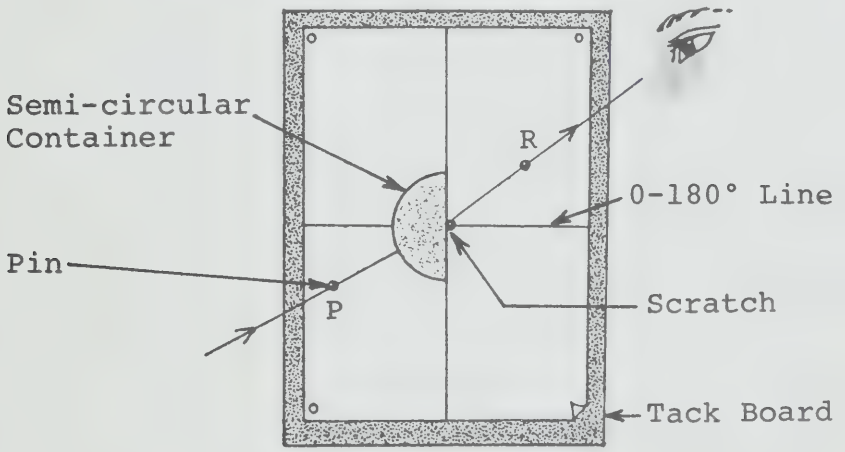
CRITICAL ANGLE FOR A LIQUID USING PINS: DIRECT METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Half fill the semi-circular plastic container with the liquid. Place a piece of polar co-ordinate paper on the tack board.

b. Place the container on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the centre (scratch) of the flat surface. The 0° end of the line should be on the curved side of the container, and the flat side of the container on the 90-270° line, as shown in the diagram.



c. Stick a pin P upright in the paper several centimetres from the curved side of the container so that the line joining P and the scratch meets the flat surface at an oblique angle.

d. Look through the container from the flat side and line up the image of the pin P and the scratch as viewed through the liquid.

e. Insert a pin R several centimetres from the flat side in a straight line with the image of P and the scratch.

f. Measure the angle of refraction of the light in passing from the liquid to air.

Method continued

g. Repeat steps c to f, increasing the angle of incidence until the angle of refraction gets as close to 90° as possible.

h. Measure the critical angle for the transparent liquid.

i. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 20

CRITICAL ANGLE FOR A LIQUID USING PINS: INDIRECT METHOD

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (30 min)

2. Minimum number of students: 1

82
287

3. Prerequisite knowledge:

   a. angle of incidence
   b. angle of refraction
   c. critical angle
   d. normal
   e. oblique angle
   f. polar co-ordinate paper

A2
A7
B3
C4

**
*
**

4. Preparation:

   a. Do not use carbon tetrachloride, carbon disulphide, turpentine, acids, bases, or methyl alcohol.

   b. Satisfactory liquids are water, cooking oil, ethylene glycol, glycerine, and a concentrated sugar solution.

   c. Make a fine vertical scratch half way down at the centre of the flat surface of the semi-circular dish using a pin or a needle.

   d. It is difficult to clean the container after the use of oils.

   e. This method involves measuring the angle of incidence and the corresponding angle of refraction, determining the index of refraction and using this to calculate the critical angle using the relationship $\sin \theta_c = 1/n$. Tables of trigonometric functions are provided to facilitate this procedure.

LABORATORY-EXPERIMENT TEST INSTRUMENT 20

CRITICAL ANGLE FOR A LIQUID USING PINS: INDIRECT METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist working in the research and development centre of a manufacturing firm. The firm has made a new transparent liquid. You have been asked to determine the critical angle of a sample of the liquid by first determining its refractive index.

Materials

- pencil
- polar co-ordinate paper
- ruler
- semi-circular plastic container
- straight pins
- tables of trigonometric functions
- tack board
- transparent liquid sample

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 20

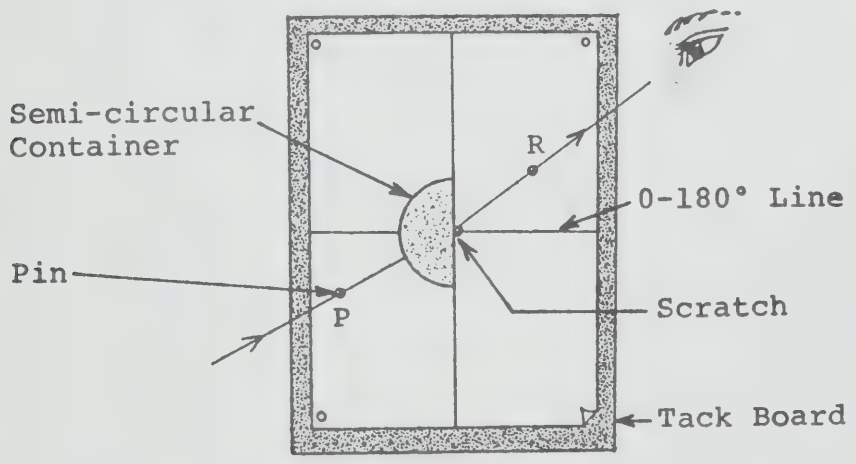
CRITICAL ANGLE FOR A LIQUID USING PINS: INDIRECT METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Half fill the semi-circular plastic container with the liquid. Place a piece of polar co-ordinate paper on the tack board.

b. Place the container on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the centre (scratch) of the flat surface. The 0° end of the line should be on the curved side of the container, and the flat side of the container on the 90-270° line as shown in the diagram.



c. Stick a pin P upright in the paper several centimetres from the curved side of the container so that the line joining P and the scratch meets the flat surface at an oblique angle.

d. Look through the container from the flat side and line up the image of the pin P and the scratch as viewed through the liquid.

e. Insert a pin R several centimetres from the flat side in a straight line with the image of P and the scratch.

f. Measure the angle of refraction of the light in passing from the liquid to air.

CRITICAL ANGLE FOR A LIQUID USING PINS: INDIRECT METHOD

Method continued

g. Determine the index of refraction of the liquid. Show all calculations.

h. Use the relationship between the critical angle and the index of refraction of the liquid to determine the critical angle for the transparent liquid. Show all calculations.

i. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 21

CRITICAL ANGLE FOR A LIQUID USING A RAY BOX: DIRECT METHOD

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

82
287
A2
A7
B3
C4
**
*
**

3. Prerequisite knowledge:

   a. angle of incidence
   b. angle of refraction
   c. critical angle
   d. normal
   e. oblique angle
   f. polar co-ordinate paper
   g. single slit aperture

4. Preparation:

   a. Do not use carbon tetrachloride, carbon disulphide, turpentine, acids, bases, or methyl alcohol.

   b. Satisfactory liquids are water, cooking oil, ethylene glycol, glycerine, and a concentrated sugar solution.

   c. Make a fine vertical scratch at the centre of the flat surface of the semi-circular dish using a pin or a needle.

   d. It is difficult to clean the container after the use of oils.

   e. This method involves increasing the angle of incidence until the critical angle is reached and measuring the critical angle directly. No tables of trigonometric functions are provided to prevent students from determining the refractive index and calculating the critical angle.

LABORATORY-EXPERIMENT TEST INSTRUMENT 21

CRITICAL ANGLE FOR A LIQUID USING A RAY BOX: DIRECT METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist working in the research and development centre of a manufacturing firm. The firm has made a new transparent liquid. You have been asked to determine the critical angle of a sample of the liquid without determining the refractive index.

Materials

pencil
polar co-ordinate paper
ray box
ruler
semi-circular plastic container
single slit aperture
transparent liquid sample

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 21

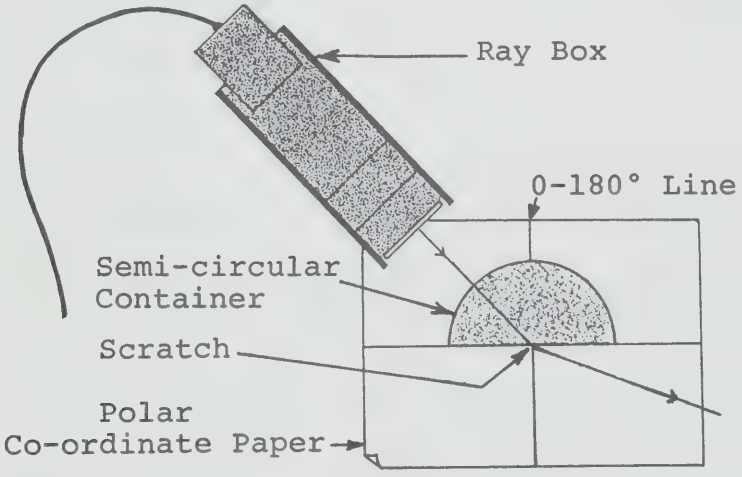
CRITICAL ANGLE FOR A LIQUID USING A RAY BOX: DIRECT METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Half fill the semi-circular plastic container with the liquid.

b. Place the container on the polar co-ordinate paper to that the 0-180° line acts as the normal and passes through the centre (scratch) of the flat surface. The 0° end of the line should be on the curved side of the container, and the flat side of the container on the 90-270° line, as shown in the diagram.



c. Direct a single ray of light toward the scratch from the curved side of the container so that the ray meets the flat surface at an oblique angle.

d. Vary the angle of incidence until an angle of refraction, as close to 90° as possible, is produced.

e. Measure the critical angle for the transparent liquid.

f. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 22

CRITICAL ANGLE FOR A LIQUID USING A RAY BOX: INDIRECT METHOD

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

82
287

3. Prerequisite knowledge:

   a. angle of incidence
   b. angle of refraction
   c. critical angle
   d. normal
   e. oblique angle
   f. polar co-ordinate paper
   g. single slit aperture

A2
A7
B3
C4

**
*
**

4. Preparation:

   a. Do not use carbon tetrachloride, carbon disulphide, turpentine, acids, bases, or methyl alcohol.

   b. Satisfactory liquids are water, cooking oil, ethylene glycol, glycerine, and a concentrated sugar solution.

   c. Make a fine vertical scratch at the centre of the flat surface of the semi-circular dish using a pin or a needle.

   d. It is difficult to clean the container after the use of oils.

   e. This method involves measuring an angle of incidence and the corresponding angle of refraction, calculating the refractive index, and then the critical angle using the relationship $\sin \theta_c = 1/n$. Tables of trigonometric functions are provided to facilitate this procedure.

LABORATORY-EXPERIMENT TEST INSTRUMENT 22

CRITICAL ANGLE FOR A LIQUID USING A RAY BOX: INDIRECT METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist working in the research and development centre of a manufacturing firm. The firm has made a new transparent liquid. You have been asked to determine the critical angle of a sample of the liquid by first determining its refractive index.

Materials

pencil
polar co-ordinate paper
ray box
ruler
semi-circular plastic container
single slit aperture
transparent liquid sample
table of trigonometric functions

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 22

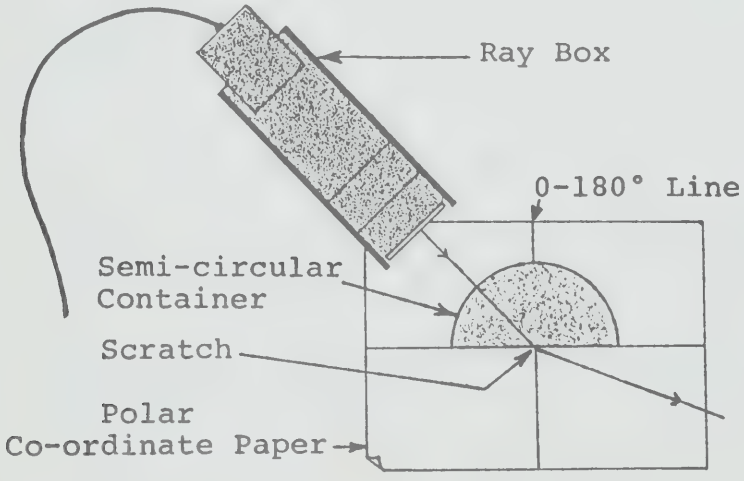
CRITICAL ANGLE FOR A LIQUID USING A RAY BOX: INDIRECT METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Half fill the semi-circular plastic container with the liquid.

b. Place the container on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the centre (scratch) of the flat surface. The 0° end of the line should be on the curved side of the container, and the flat side of the container on the 90-270° line, as shown in the diagram.



c. Direct a single ray of light toward the scratch from the curved side of the container so that the ray meets the flat surface at an oblique angle.

d. Measure the angle of incidence and the corresponding angle of refraction.

e. Calculate the refractive index of the liquid in the container. Show all calculations.

f. Calculate the critical angle for the transparent liquid. Show all calculations.

g. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 23

CRITICAL ANGLE FOR A SOLID USING A RAY BOX: DIRECT METHOD

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

82
287

3. Prerequisite knowledge:

   a. angle of incidence
   b. angle of refraction
   c. critical angle
   d. normal
   e. oblique angle
   f. polar co-ordinate paper
   g. single slit aperture

A2
A7
B3
C4

**
*
**

4. Preparation:

   a. Use either transparent plastic or glass.

   b. Draw a vertical line half way down at the centre of the flat surface of the semi-circular solid using a fine permanent marker pen.

   c. This method involves increasing the angle of incidence until the critical angle is reached and measuring it directly.

LABORATORY-EXPERIMENT TEST INSTRUMENT 23

CRITICAL ANGLE FOR A SOLID USING A RAY BOX: DIRECT METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technician working in a factory which manufactures optical instruments. The firm has made a new semi-circular transparent solid. You have been asked to determine the critical angle for the solid without determining the refractive index.

Materials

marking pen
pencil
polar co-ordinate paper
ray box
ruler
semi-circular transparent solid
slit aperture

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 23

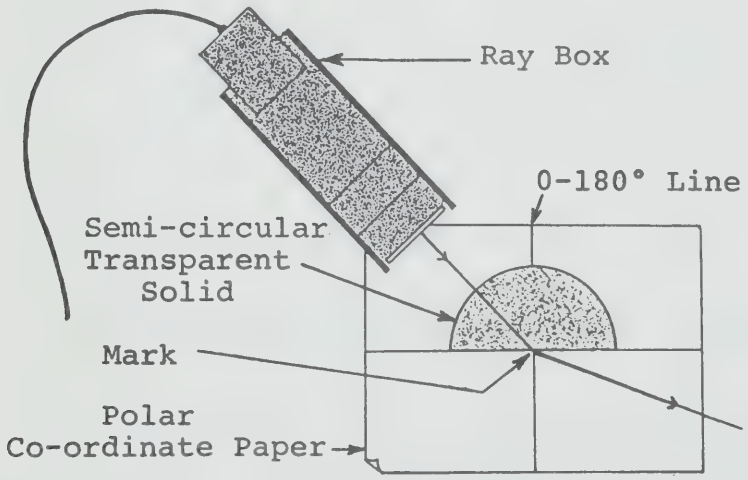
CRITICAL ANGLE FOR A SOLID USING A RAY BOX: DIRECT METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Mark a vertical line at the centre of the flat surface of the semi-circular solid.

b. Place the semi-circular solid on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the mark, and the flat surface is along the 90-270° line.



c. Direct a single ray of light toward the mark from the curved side of the block so that the ray meets the flat surface at an oblique angle.

d. Vary the angle of incidence until an angle of refraction as close to 90° as possible is produced.

e. Measure the critical angle for the transparent solid.

f. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 24

CRITICAL ANGLE FOR A SOLID USING A RAY BOX: INDIRECT METHOD

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

82
287

3. Prerequisite knowledge:

   a. angle of incidence
   b. angle of refraction
   c. critical angle
   d. normal
   e. oblique angle
   f. polar co-ordinate paper
   g. single slit aperture

A2
A7
B3
C4

**
*
**

4. Preparation:

   a. Use either transparent plastic or glass.

   b. Draw a vertical line half way down at the centre of the flat surface of the semi-circular solid using a fine permanent marker pen.

   c. This method involves measuring an angle of incidence and the corresponding angle of refraction, calculating the refractive index and using it to calculate the critical angle.

LABORATORY-EXPERIMENT TEST INSTRUMENT 24

CRITICAL ANGLE FOR A SOLID USING A RAY BOX: INDIRECT METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technician working in a factory which manufactures optical instruments. The firm has made a new semi-circular transparent solid. You have been asked to determine the critical angle for the solid by first determining its refractive index.

Materials

marking pen
pencil
polar co-ordinate paper
ray box
ruler
semi-circular transparent solid
slit aperture
table of trigonometric functions

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 24

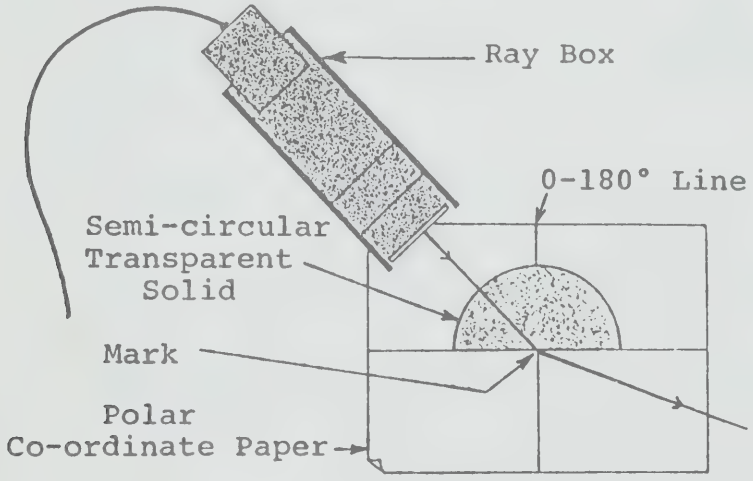
CRITICAL ANGLE FOR A SOLID USING A RAY BOX: INDIRECT METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Mark a vertical line at the centre of the flat surface of the semi-circular solid.

b. Place the semi-circular solid on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the mark, and the flat surface is along the 90-270° line.



c. Direct a single ray of light toward the mark from the curved side of the block so that the ray meets the flat surface at an oblique angle.

d. Measure the angle of refraction, and the angle of incidence.

e. Calculate the refractive index of the solid. Show all calculations.

f. Calculate the critical angle for the solid. Show all calculations.

g. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 25

CRITICAL ANGLE FOR A SOLID USING PINS: DIRECT METHOD

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (20 min)
2. Minimum number of students: 1

82
287
A2
A7
B3
C4

3. Prerequisite knowledge:
   a. angle of incidence
   b. angle of refraction
   c. critical angle
   d. normal
   e. oblique angle
   f. polar co-ordinate paper

**
*
**

4. Preparation:
   a. Use either transparent plastic or glass.
   b. Draw a vertical line half way down at the centre of the flat surface of the semi-circular solid using a fine permanent marker pen.
   c. This method involves increasing the angle of incidence until the critical angle is reached and measuring it directly.

LABORATORY-EXPERIMENT TEST INSTRUMENT 25

CRITICAL ANGLE FOR A SOLID USING PINS: DIRECT METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist working for a large telecommunications firm. A new material needs to have its critical angle determined before it can be used in a light pipe communication device. Your task is to determine the critical angle for the solid without determining the refractive index.

Materials

marking pen
pencil
polar co-ordinate paper
ruler
semi-circular solid
straight pins
tack board

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 25

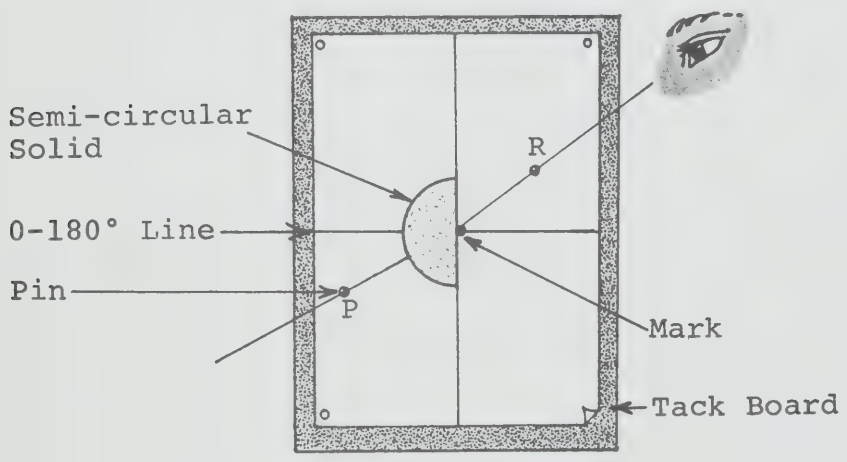
CRITICAL ANGLE FOR A SOLID USING PINS: DIRECT METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Mark a vertical line at the centre of the flat surface of the semi-circular solid. Place a sheet of polar co-ordinate paper on the tack board.

b. Place the semi-circular solid on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the mark, and the flat side is on the 90-270° line.



c. Stick a pin P upright in the paper several centimetres from the curved side of the solid so that the line joining P and the mark meets the flat surface at an oblique angle.

d. Look through the solid from the flat side and line up with the image of P and the vertical line at the centre of the flat surface.

e. Insert a pin R several centimetres from the flat side in a straight line with the image of P and the vertical line.

f. Vary the angle of incidence until an angle of refraction as close to 90° as possible is produced.

CRITICAL ANGLE FOR A SOLID USING PINS: DIRECT METHOD

Method continued

g. Measure the critical angle of the transparent solid.

h. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 26

CRITICAL ANGLE FOR A SOLID USING PINS: INDIRECT METHOD

Notes to the Teacher

S17A
II.3.a
S17C
II.1.b

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (20 min)
2. Minimum number of students: 1

82
287

3. Prerequisite knowledge:

A2
A7
B3
C4

   a. angle of incidence
   b. angle of refraction
   c. critical angle
   d. normal
   e. oblique angle
   f. polar co-ordinate paper

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*
**

4. Preparation:

   a. Use either transparent plastic or glass.

   b. Draw a vertical line half way down at the centre of the flat surface of the semi-circular solid using a fine permanent marker pen.

   c. This method involves measuring an angle of incidence and the corresponding angle of refraction, calculating the refractive index and using it to calculate the critical angle.

LABORATORY-EXPERIMENT TEST INSTRUMENT 26

CRITICAL ANGLE FOR A SOLID USING PINS: INDIRECT METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist working for a large telecommunications firm. A new material needs to have its critical angle determined before it can be used in a light pipe communication device. Your task is to determine the critical angle for the solid by first determining the refractive index.

Materials

marking pen
pencil
polar co-ordinate paper
ruler
semi-circular solid
straight pins
table of trigonometric functions
tack board

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 26

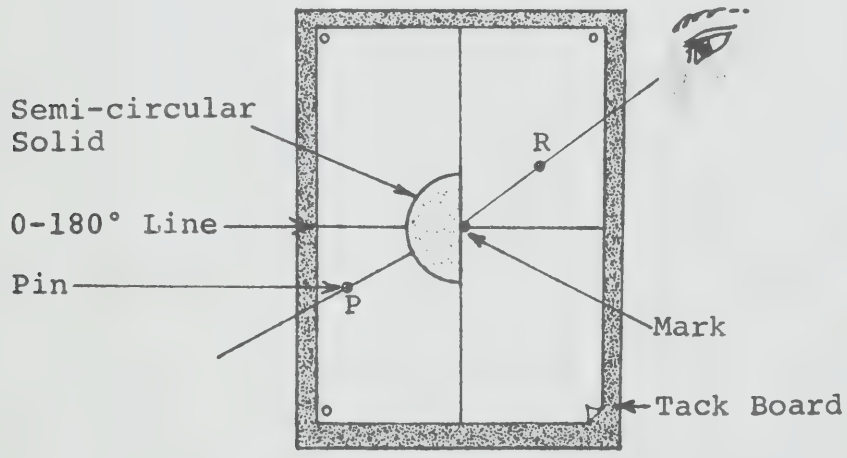
CRITICAL ANGLE FOR A SOLID USING PINS: INDIRECT METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Mark a vertical line at the centre of the flat surface of the semi-circular solid. Place a sheet of polar co-ordinate paper on the tack board.

b. Place the semi-circular solid on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the mark, and the flat side is on the 90-270° line.



c. Stick a pin P upright in the paper several centimetres from the curved side of the solid so that the line joining P and the mark meets the flat surface at an oblique angle.

d. Look through the solid from the flat side and line up with the image of P and the vertical line at the centre of the flat surface.

e. Insert a pin R several centimetres from the flat side in a straight line with the image of P and the vertical line.

f. Measure the angle of incidence and the corresponding angle of refraction of the light in passing from the solid to air.

CRITICAL ANGLE FOR A SOLID USING PINS: INDIRECT METHOD

Method continued

g. Calculate the refractive index of the solid. Show all calculations.

h. Calculate the critical angle for the solid. Show all calculations.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 27

INDEX OF REFRACTION USING WATER WAVES

Notes to the Teacher

S17C
II.4.c

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (30 min)

82

2. Minimum number of students: 2

A7
A8
B3
C4
D3

-
**
-

3. Prerequisite knowledge:

   a. angle of incidence
   b. angle of refraction
   c. incident wave front
   d. interface
   e. normal
   f. oblique angle
   g. refracted wave front
   h. refraction
   i. sine

4. Preparation:

   a. Use dampers to minimize reflection from the edges.

   b. Level the tank carefully.

   c. The water over the refraction plate must be very shallow to get visible refracted waves.

   d. You will have to do the experiment ahead of time to determine a reasonable value.

   e. Set up the ripple tank and accessories ahead of time to decrease the time needed for the experiment.

5. CAUTION:

   LIGHT BULBS COATED BLACK BECOME VERY HOT AND CAN IMPLODE IF THEY COME IN CONTACT WITH WATER.

LABORATORY-EXPERIMENT TEST INSTRUMENT 27

INDEX OF REFRACTION USING WATER WAVES

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Determine the index of refraction for water waves moving from deep to shallow water. Draw a diagram showing the interface, an incident and refracted wave front, the normal, and the angles of incidence and refraction.

Materials

- dampers
- hand stroboscope
- metre stick
- paper screen
- periodic plane wave generator
- protractor
- ripple tank
- sine tables
- straight barriers
- transparent refraction plate and spacers
- two metric rulers
- wedges for levelling ripple tank

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

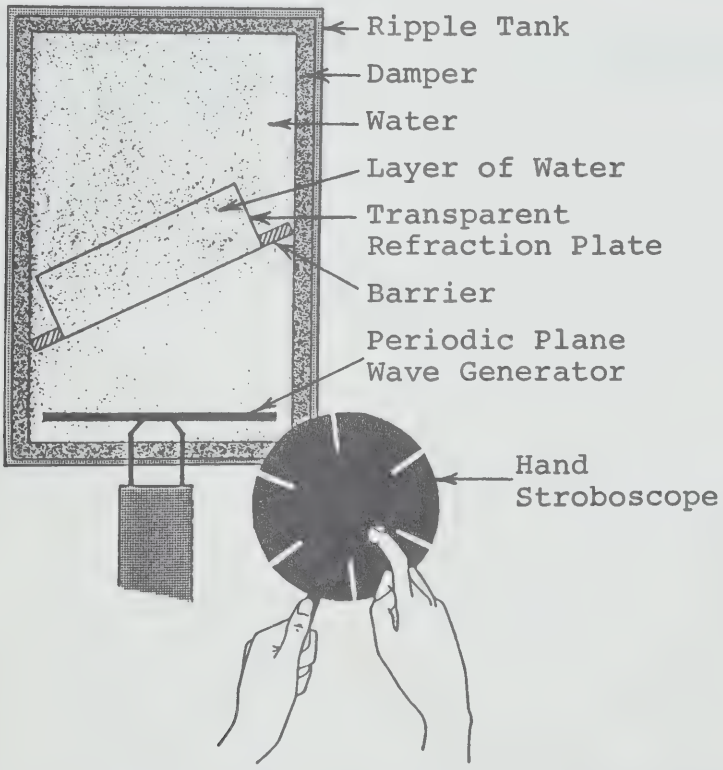
PROCEDURE SHEET 27

INDEX OF REFRACTION USING WATER WAVES

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the periodic plane wave generator near the interface between the deep and shallow water as shown in the diagram.



b. Direct plane periodic waves toward the interface at an oblique angle.

c. Draw on the screen the image of the interface between deep and shallow water.

d. View the incident and refracted wave fronts through the hand stroboscope.

e. Place rulers on the screen parallel to the incident and refracted wave fronts.

Method continued

f. Measure the angle of incidence and the angle of refraction.

g. Calculate the index of refraction for waves travelling from deep to shallow water. Show all calculations.

h. Draw a diagram showing the interface, an incident and a refracted wave front, the normal, and the angles of incidence and refraction.

i. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 28

SPEED OF LIGHT IN A SOLID USING A RAY BOX

Notes to the Teacher

S17A
II.3.a
S17C
II.6.d

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

82

3. Prerequisite knowledge:

A8
C4
D1
D3
*
\-
**

a. angle of incidence i
b. angle of refraction R
c. incident, refracted, and emergent rays
d. index of refraction
e. normal
f. oblique angle
g. refraction
h. sine
i. speed
j. $n = \frac{\sin i}{\sin R} = \frac{V_{air}}{V_{sample}}$

4. Preparation:

   Use either transparent rectangular plastic or glass prisms.

LABORATORY-EXPERIMENT TEST INSTRUMENT 28

SPEED OF LIGHT IN A SOLID USING A RAY BOX

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist in the research and development centre of a telecommunications firm. The firm has made a new transparent solid to be used in fibre optics communication. You have been asked to determine the speed of light in the solid. The speed of light in air is 3.0×10^8 m/s.

Materials

pencil	ruler
protractor	sheet of paper
ray box	sine tables
rectangular transparent solid	single slit aperture

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 28

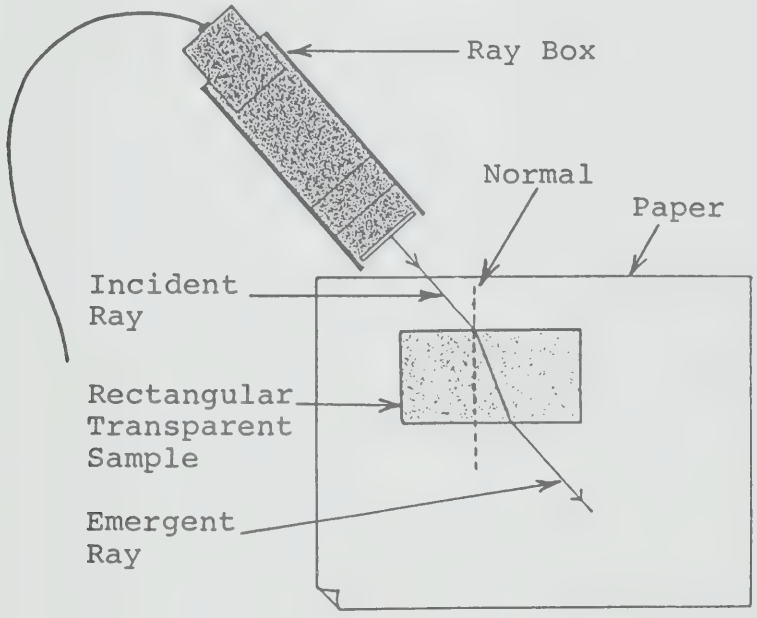
SPEED OF LIGHT IN A SOLID USING A RAY BOX

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the rectangular transparent sample on the sheet of paper. With a pencil, outline the edges of the sample.

b. Direct a single ray of light at an oblique angle toward one edge of the sample as shown in the diagram.



c. Mark the path of the incident and emergent rays.

d. Remove the transparent sample and draw the path of the refracted ray.

e. Draw the normal at the point of incidence.

f. Measure and record the angle of incidence and the angle of refraction.

g. Determine the index of refraction of the sample. Show all calculations.

SPEED OF LIGHT IN A SOLID USING A RAY BOX

Method continued

h. Use the relationship between the refractive index and the speed of light in air to determine the speed of light in the transparent sample. Show all calculations.

i. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 29

SPEED OF LIGHT IN A SOLID USING PINS

Notes to the Teacher

S17A
II.3.a
S17C
II.6.d

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (25 min)

2. Minimum number of students: 1

82

3. Prerequisite knowledge:

A8
C4
D1
D3

a. angle of incidence i
b. angle of refraction R
c. incident ray
d. index of refraction
e. normal
f. oblique angle
g. refracted ray
h. refraction
i. sine
j. speed
k. $n = \frac{\sin i}{\sin R} = \frac{V_{air}}{V_{sample}}$

*
-
**

4. Preparation:

   Use either a transparent rectangular plastic or glass prism.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 29

SPEED OF LIGHT IN A SOLID USING PINS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist in the research and development centre of a telecommunications firm. The firm has made a new transparent solid to be used in fibre optics communication. You have been asked to determine the speed of light in the solid. The speed of light in air is 3.0×10^8 m/s.

Materials

four straight pins
pencil
protractor
rectangular transparent solid
ruler
sheet of paper
sine tables
tack board

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 29

SPEED OF LIGHT IN A SOLID USING PINS

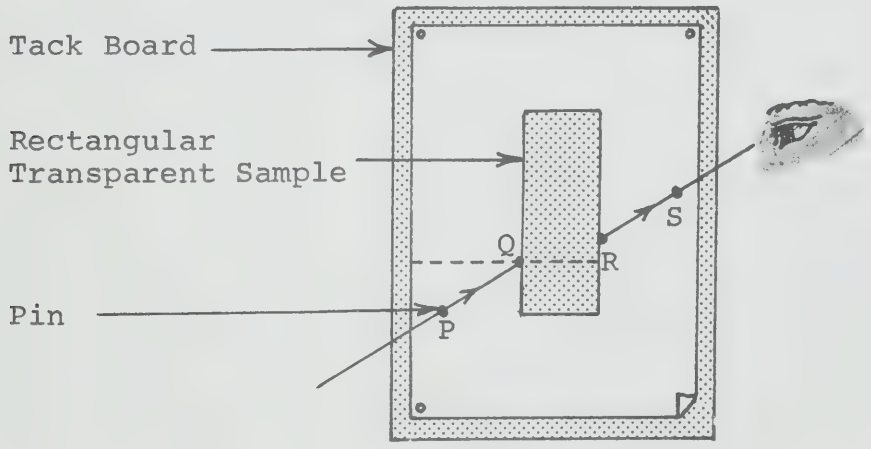
Note: Return this sheet to your examiner at the end of the test.

Method

a. Place a sheet of paper on the tack board. Place the rectangular solid sample on the sheet of paper. With a pencil, outline the edges of the sample.

b. Stick a pin Q upright in the paper so that it touches one edge of the sample.

c. Stick another pin P upright in the paper several centimetres from pin Q so that the line joining PQ meets the edge of the solid at an oblique angle as shown in the diagram.



d. Look through the solid from the opposite side and line up the images of pins P and Q.

e. Insert two pins, R and S, several centimetres apart on this side of the solid with R touching the edge of the solid so that they line up with P and Q as viewed through the sample.

f. Mark the position of each pin, remove the pins and solid, and join PQ, QR, and RS.

g. Draw the normal at the point of incidence.

SPEED OF LIGHT IN A SOLID USING PINS

Method continued

h. Measure and record the angle of incidence and the angle of refraction.

i. Determine the index of refraction of the sample. Show all calculations.

j. Use the relationship between the refractive index and the speed of light in air to determine the speed of light in the transparent sample. Show all calculations.

k. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 30

SPEED OF LIGHT IN A LIQUID USING PINS

Notes to the Teacher

S17A
II.3.a
S17C
II.6.d

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (25 min)

2. Minimum number of students: 1

82

3. Prerequisite knowledge:

A8
C4
D1
D3
*
-
**

a. angle of incidence i
b. angle of refraction R
c. incident ray
d. index of refraction
e. normal
f. oblique
g. polar co-ordinate paper
h. refracted ray
i. refraction
j. sine
k. speed
l. $n = \frac{\sin i}{\sin R} = \frac{V_{air}}{V_{sample}}$

4. Preparation:

   a. Do not use carbon tetrachloride, carbon disulphide, turpentine, acids, bases, or methyl alcohol.

   b. Satisfactory liquids are water, cooking oil, ethylene glycol, glycerine, and a concentrated sugar solution.

   c. It is difficult to clean the container after the use of oils.

LABORATORY-EXPERIMENT TEST INSTRUMENT 30

SPEED OF LIGHT IN A LIQUID USING PINS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist in the research and development centre of a large firm. A field worker has just brought in a sample of an unknown liquid. You are to determine the speed of light in the liquid. The speed of light in air is 3.0×10^8 m/s.

Materials

liquid	semi-circular plastic container
pencil	sine tables
polar co-ordinate paper	straight pins
ruler	tack board

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 30

SPEED OF LIGHT IN A LIQUID USING PINS

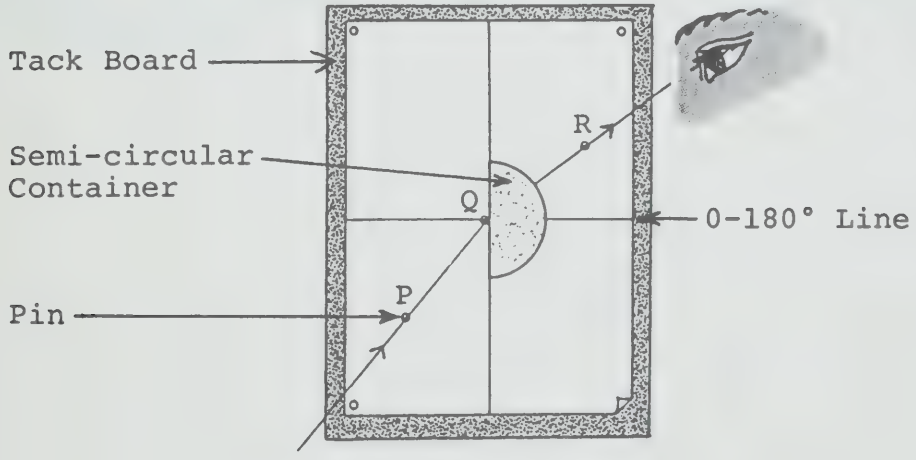
Note: Return this sheet to your examiner at the end of the test.

Method

a. Place a sheet of polar co-ordinate paper on a tack board.

b. Half fill the semi-circular plastic container with the liquid.

c. Place the container on the polar co-ordinate paper so that the 0-180° line acts as the normal and passes through the centre (scratch) of the flat surface. The flat side of the container must be along the 90-270° line.



d. Label the scratch Q.

e. Stick a pin P upright in the paper several centimetres from Q so that the line joining PQ meets the edge of the container at an oblique angle.

f. Look through the container from the curved side and line up the images of pin P and the scratch Q.

g. Insert a pin R several centimetres from the curved side of the container. Align the images of pin P and the scratch Q with pin R.

SPEED OF LIGHT IN A LIQUID USING PINS

Method continued

h. Mark the position of each pin, remove the pins and the container and join PQ and QR.

i. Measure and record the angle of incidence and the angle of refraction.

j. Determine the index of refraction of the liquid. Show all calculations.

k. Use the relationship between the refractive index and the speed of light in air to determine the speed of light in the transparent liquid. Show all calculations.

l. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 31

SPEED OF LIGHT IN A LIQUID USING A RAY BOX

Notes to the Teacher

S17A
II.3.a
S17C
II.6.d

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

82

3. Prerequisite knowledge:

A8
C4
D1
D3
*
-
**

a. angle of incidence i
b. angle of refraction R
c. incident ray
d. index of refraction
e. normal
f. oblique
g. polar co-ordinate paper
h. refracted ray
i. refraction
j. sine
k. speed
l. $n = \frac{\sin i}{\sin R} = \frac{V_{air}}{V_{sample}}$

4. Preparation:

a. Do not use carbon tetrachloride, carbon disulphide, turpentine, acids, bases, or methyl alcohol.

b. Satisfactory liquids are water, cooking oil, ethylene glycol, glycerine, and a concentrated sugar solution.

c. It is difficult to clean the container after the use of oils.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 31

SPEED OF LIGHT IN A LIQUID USING A RAY BOX

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a physicist in the research and development centre of a large firm. A field worker has just brought in a sample of an unknown liquid. You are to determine the speed of light in the liquid. The speed of light in air is 3.0×10^8 m/s.

Materials

liquid	ruler
pencil	semi-circular plastic container
polar co-ordinate paper	single slit aperture
ray box	sine tables

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 31

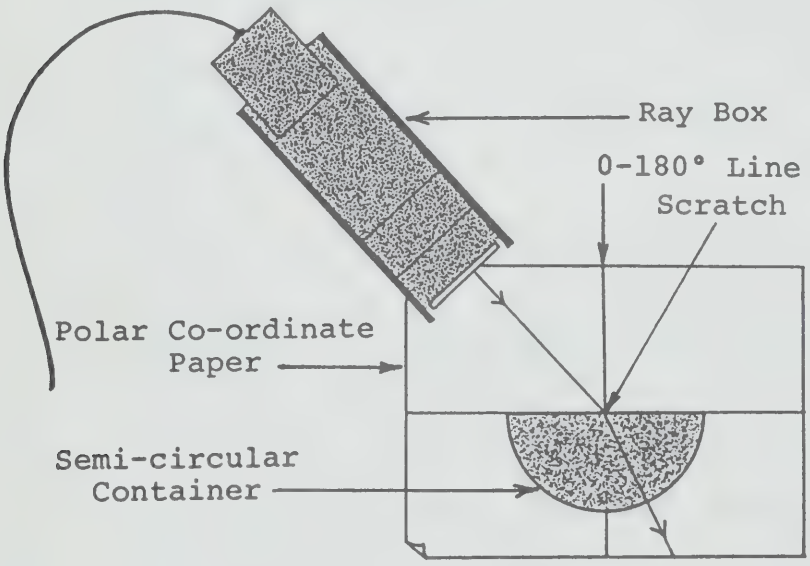
SPEED OF LIGHT IN A LIQUID USING A RAY BOX

Note: Return this sheet to your examiner at the end of the test.

Method

a. Half fill the semi-circular plastic container with the liquid.

b. Place the container on the polar co-ordinate graph paper so that the 0-180° line acts as the normal and passes through the centre (scratch) of the flat surface. The flat surface must be on the 90-270° line.



c. Direct a single ray of light toward the scratch at an oblique angle.

d. Record the angle of incidence and the angle of refraction.

e. Determine the index of refraction. Show all calculations.

f. Use the relationship between the refractive index and the speed of light in air to determine the speed of light in the transparent liquid. Show all calculations.

g. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 32

THICKNESS OF A THIN MATERIAL USING AN AIR WEDGE

Notes to the Teacher

S17C
II.6.c

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (30 min)

SS 84

2. Minimum number of students: 1

B4
C4
D1

3. Prerequisite knowledge:

   a. air wedge

   b. distance between adjacent dark bands Δx

   c. interference

   d. length of plates L

   e. monochromatic

   f. thickness t

   g. wavelength of light λ

   h. $t = \frac{L\lambda}{2\Delta x}$

4. Preparation:

   a. Choose pairs of plane, rectangular glass plates.

   b. Provide a thin material which yields a realistic spacing of interference bands. Hair, aluminum foil, cigarette paper, and plastic films work well.

   c. Provide the wavelength of the light in nanometres.

   d. If a sodium arc lamp is used as the source, warm it up ahead of time.

   e. Expect a considerable variation in the results.

LABORATORY-EXPERIMENT TEST INSTRUMENT 32

THICKNESS OF A THIN MATERIAL USING AN AIR WEDGE

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working as a technician in a forensic science laboratory. A thin material has been found at the scene of a crime. Your problem is to determine the thickness of the material using an indirect method.

Materials

2 long, thick, planed glass plates

metric ruler

near-monochromatic light source of known wavelength (e.g. sodium arc lamp)

rubber bands

sample of thin material of unknown thickness

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) **Under the heading "Problem" write in your own words a clear statement of the problem under investigation.**

b) **Examine the materials supplied by your examiner.**

c) **Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.**

d) **Under the heading "Method" list in order the steps of the method you will use to solve the problem.**

e) **When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.**

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

PROCEDURE SHEET 32

THICKNESS OF A THIN MATERIAL USING AN AIR WEDGE

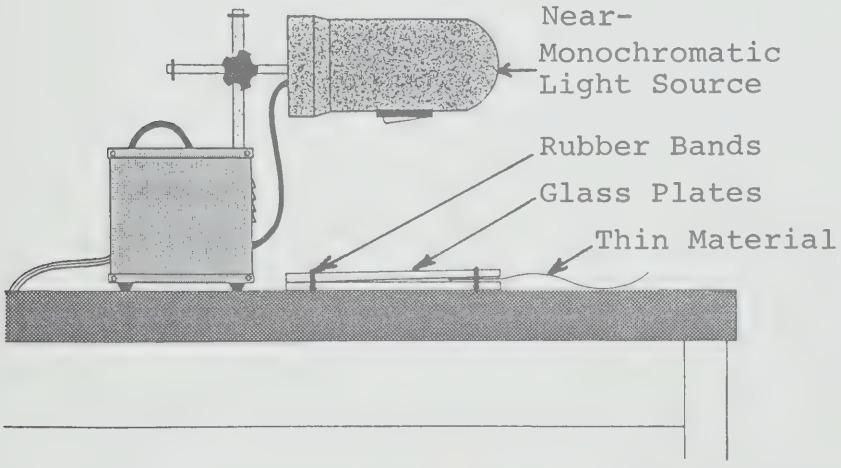
Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the two long, thick, planed glass plates on top of one another on a level surface.

b. Create a thin air wedge by placing the thin material between the plates at one end and holding them together using rubber bands.

c. Illuminate the plates from directly above with light from the near-monochromatic source as shown in the diagram.



d. View the interference pattern on the plates from directly above.

e. Count the number of bright bands over a measured distance. A bright band extends from the centre of a dark band to the centre of an adjacent dark band.

f. Calculate the average distance between the dark bands.

g. Measure the total length of the air wedge.

h. Obtain and record the wavelength of the near-monochromatic light from the examiner.

Method continued

i. Use the relationship among the variables to calculate the thickness of the object. Show all calculations.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 33

WAVELENGTH OF LIGHT USING AN AIR WEDGE

Notes to the Teacher

S17C
II.6.c

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (30 min)

SS 84

2. Minimum number of students: 1

B4
C4
D1

3. Prerequisite knowledge:

   a. air wedge

   b. distance between adjacent dark bands Δx

   c. interference

   d. length of plates L

   e. monochromatic

   f. thickness t

   g. wavelength of light λ

   h. $t = \frac{L\lambda}{2\Delta x}$

4. Preparation:

   a. Choose pairs of plane, rectangular glass plates.

   b. Provide a thin material which yields a realistic spacing of interference bands. Hair, aluminum foil, cigarette paper, and plastic films work well.

   c. Provide the thickness of the thin material.

   d. Obtain the thickness using a micrometer screw gauge.

   e. Expect a considerable variation in the results.

   f. If a sodium arc lamp is used as the source, warm it up ahead of time.

LABORATORY-EXPERIMENT TEST INSTRUMENT 33

WAVELENGTH OF LIGHT USING AN AIR WEDGE

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist working for a firm which manufactures sources of light. The firm has produced a new near-monochromatic light source. Your problem is to determine the wavelength of the light from the near-monochromatic source.

Materials

metric ruler

near-monochromatic light source of unknown wavelength (e.g. sodium arc lamp)

thin material of known thickness

2 long, thick, planed glass plates

2 rubber bands

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 33

WAVELENGTH OF LIGHT USING AN AIR WEDGE

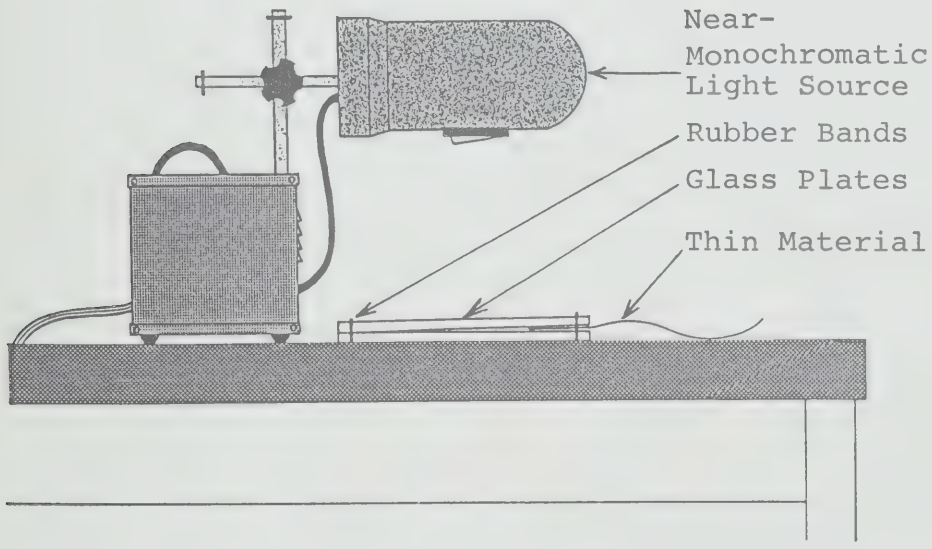
Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the two long, thick, planed glass plates on top of one another on a level surface.

b. Create a thin air wedge by placing the thin object between the plates at one end. Hold the plates together with rubber bands.

c. Illuminate the plates from directly above with light from the near-monochromatic source as shown in the diagram.



d. View the interference pattern on the plates from directly above.

e. Count the number of bright bands over a measured distance. A bright band extends from the centre of a dark band to the centre of an adjacent dark band.

f. Calculate the average distance between the dark bands.

g. Measure the total length of the air wedge.

Method continued

h. Obtain and record the thickness of the object from the examiner.

i. Use the relationship among the variables to calculate the wavelength of the light. Show all calculations.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 34

INTERFERENCE OF WATER WAVES

Notes to the Teacher

S17C
II.5.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (25 min)

85

2. Minimum number of students: 2

A7
A8
B3
C4
D3

3. Prerequisite knowledge:

   a. distance between the point sources d

   b. distance from the point P to the mid point between the point sources L

\-

   c. frequency

**

   d. in phase

\-

   e. number of the nodal line n

   f. perpendicular distance from the point P to the centre line x_n

   g. point P on a nodal line far from the point sources

   h. point sources

   i. wavelength of the water waves λ

   j. $\lambda = \dfrac{d\, x_n}{L(n - \frac{1}{2})}$

4. Preparation:

   a. Tell students to make all measurements on the screen.

   b. The wavelength is the wavelength on the screen, not in the ripple tank.

   c. Preset the wave generator to produce vibrations of the two point sources that are in phase.

   d. Set up the ripple tank and accessories ahead of time to minimize the time required for the experiment.

   e. Adjust the wave generator so that the two point sources vibrate in phase.

LABORATORY-EXPERIMENT TEST INSTRUMENT 34

INTERFERENCE OF WATER WAVES

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you have applied for a job with an engineering firm that manufactures machines to harness the energy in water waves. Your task is to determine the wavelength of the image of water waves projected on a screen by using the interference pattern from two in-phase point sources in a ripple tank.

Materials

dampers
metre stick
periodic wave generator
2 point sources
ripple tank
screen
wedges for levelling the ripple tank

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 34

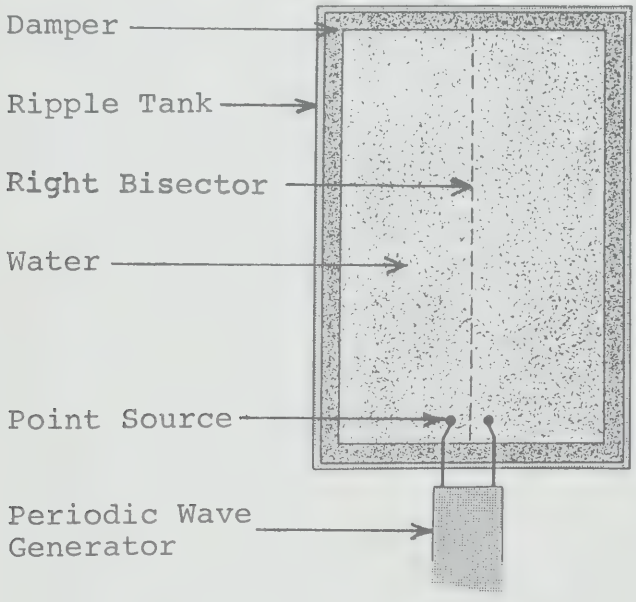
INTERFERENCE OF WATER WAVES

Note: Return this sheet to your examiner at the end of the test.
Make all measurements on the screen beneath the ripple tank.

Method

a. Generate periodic water waves from the two sources. Adjust the frequency and the separation of the sources to produce a distinct interference pattern.

b. Construct the right bisector of the line joining the two point sources as shown in the diagram.



c. Select a convenient nodal line on the screen. On this nodal line, select a point P far from the point sources.

d. Measure and record the distance from the point P to the mid point between the point sources.

e. Measure and record the distance between the point sources.

f. Measure and record the perpendicular distance from the point P to the centre line.

g. Record the number of the nodal line on which P is located, counting from the centre line out.

Method continued

h. Use the relationship among the variables to calculate the wavelength of the water waves on the screen. Show all calculations.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 35

WAVELENGTH OF FILTERED LIGHT

Notes to the Teacher

S17C
II.6.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (30 min)

86

2. Minimum number of students: 2

B4
C4
D1

3. Prerequisite knowledge:

   a. distance between the adjacent dark bands Δx

   b. distance between the slits d

**

   c. frequency

   d. in phase

   e. perpendicular distance from the slits to the screen or from the slits to the reference metre stick L

   f. wavelength of the light λ

   g. $\lambda = \frac{d\ \Delta x}{L}$

4. Preparation:

   a. Several variations are possible by using different coloured filters. However red is the easiest filter for students.

   b. Provide the students with the slit separation.

   c. Make sure the filter is large enough to completely wrap around the bulb.

   d. If more than one set up is used, position them as far apart as possible.

LABORATORY-EXPERIMENT
TEST INSTRUMENT 35

WAVELENGTH OF FILTERED LIGHT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a research scientist working for a company that manufactures light filters. The firm has produced a filter from a new material. Your problem is to design and implement a method using a double slit to determine the wavelength of the light passing through the filter.

Materials

double slit of known separation
elastic bands
filter of unknown wavelength range
line filament bulb, socket and clamp
masking tape
metre stick
retort stand
sliding markers for metre stick

CAUTION: THE LINE FILAMENT BULB WILL GET HOT.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 35

WAVELENGTH OF FILTERED LIGHT

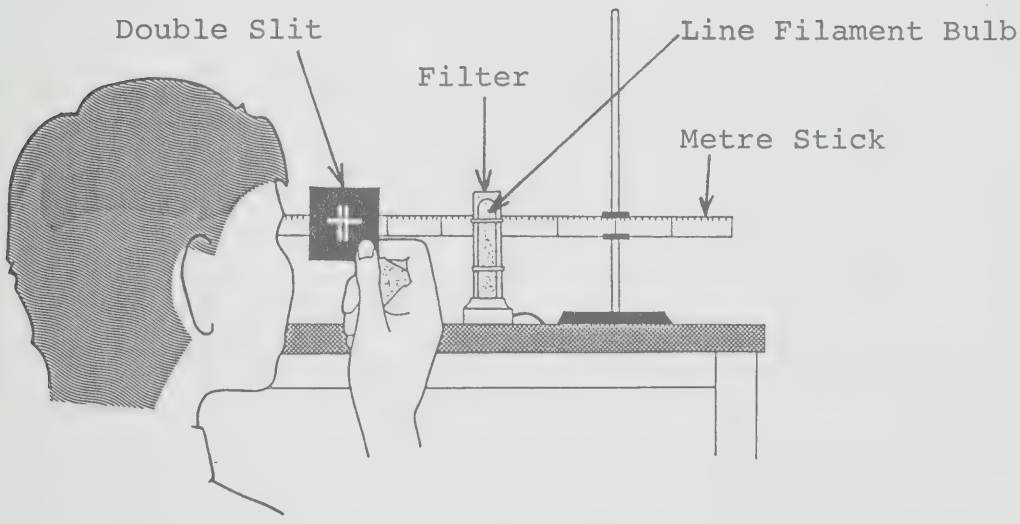
Note: Return this sheet to your examiner at the end of the test.

Method

a. Position the bulb with the line filament in a vertical position.

b. Cover the bulb with the filter using the rubber bands.

c. Position a reference metre stick in a horizontal position immediately behind the filament of the bulb as shown in the diagram.



d. Hold the double slit at least two metres from the light source.

e. Measure and record the distance from the double slit to the metre stick.

f. Look through the double slit and superimpose the image of the interference pattern onto the metre stick.

g. Measure and record the distance across a known number of minima (nodal lines).

h. Calculate and record the separation between the centres of adjacent minima.

Method continued

i. Obtain from the examiner the slit separation in metres. Record this value.

j. Use the relationship among the variables to calculate the wavelength of the filtered light. Show all calculations.

k. When you have finished the report, submit the procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 36

DOUBLE SLIT SEPARATION USING A LINE FILAMENT BULB

Notes to the Teacher

S17C
III.6.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (30 min)

86

2. Minimum number of students: 2

D1
C4
C3
B4

3. Prerequisite knowledge:

   a. distance between the adjacent dark bands Δx

   b. distance between the slits d

\-

   c. frequency

**

   d. in phase

\-

   e. perpendicular distance from the slits to the screen or from the slits to the reference metre stick L

   f. wavelength of the light λ

   g. $\lambda = \frac{d\,\Delta x}{L}$

4. Preparation:

   a. Several variations are possible by using different coloured filters. However, red is the easiest filter to use.

   b. Provide the students with the wavelength of the filter.

   c. Make sure the filter is large enough to completely wrap around the bulb.

   d. If more than one set up is used, position them as far apart as possible.

LABORATORY-EXPERIMENT TEST INSTRUMENT 36

DOUBLE SLIT SEPARATION USING A LINE FILAMENT BULB

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Sometimes physicists use an indirect method to determine the dimension(s) of an object or physical quantity. Your problem is to design and implement a method to indirectly determine the separation between two slits.

Materials

- double slit of unknown separation
- elastic bands
- filter of known wavelength
- line filament bulb, socket and clamp
- masking tape
- metre stick
- retort stand
- sliding markers for the metre stick

CAUTION: THE LINE FILAMENT BULB WILL GET HOT

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 36

DOUBLE SLIT SEPARATION USING A LINE FILAMENT BULB

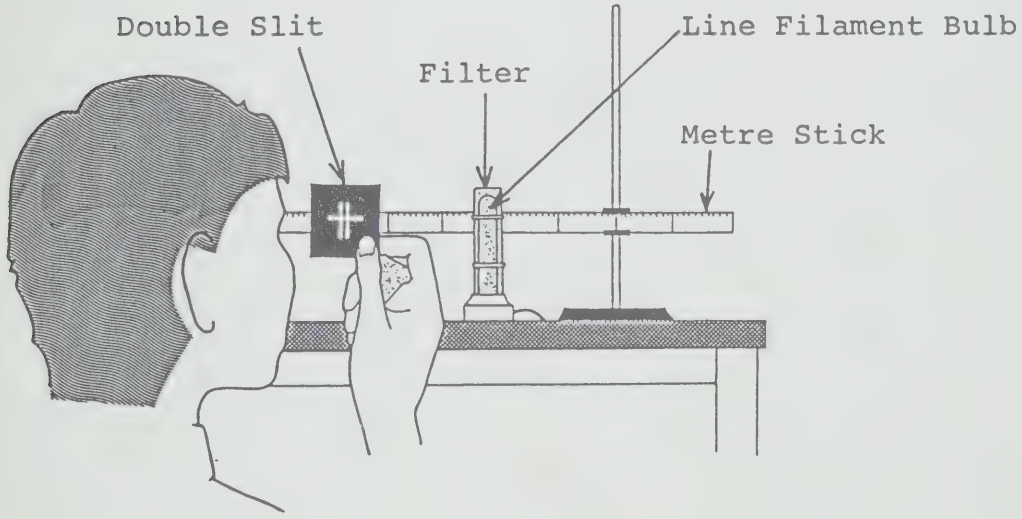
Note: Return this sheet to your examiner at the end of the test.

Method

a. Position the bulb in a vertical position.

b. Cover the bulb with the filter using the rubber bands.

c. Position a metre stick in a horizontal position behind the filament of the bulb as shown in the diagram.



d. Hold the double slit at least two metres from the light source.

e. Measure and record the distance from the double slit to the metre stick.

f. Look through the double slit and superimpose the image of the interference pattern onto the metre stick.

g. Measure and record the distance across a known number of minima.

Method continued

h. Calculate and record the separation between the centres of adjacent minima.

i. Obtain from the examiner the wavelength of the light passing through the filter.

j. Use the relationship among the variables to calculate the slit separation. Show all calculations.

k. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 37

WAVELENGTH OF LASER LIGHT

Notes to the Teacher

S17C
II.6.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (25 min)

86

2. Minimum number of students: 2

D1
C4
B4

3. Prerequisite knowledge:

-
**
-

   a. distance between the adjacent dark bands Δx

   b. distance between the slits d

   c. frequency

   d. in phase

   e. perpendicular distance from the slits to the screen or from the slits to the reference metre stick L

   f. wavelength of the light λ

   g. $\lambda = \frac{d\ \Delta x}{L}$

4. Preparation:

   a. Provide the students with the slit separation.

   b. Check ahead of time that the laser tube is operating.

5. CAUTIONS:

   a. LIGHT FROM THE LASER CAN BE HARMFUL TO THE EYES.

   b. DO NOT LOOK DIRECTLY INTO THE LASER BEAM.

   c. POSITION THE LASER BEAM SO THAT IT DOES NOT CROSS A TRAFFIC AREA OR REFLECT FROM A SHINY OBJECT.

   d. CLAMP THE LASER FIRMLY IN PLACE.

LABORATORY-EXPERIMENT TEST INSTRUMENT 37

WAVELENGTH OF LASER LIGHT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you work for a scientist who has invented a new laser. The scientist wishes to verify the wavelength of the light it produces. Your problem is to design and implement a method to determine the wavelength of the light from the laser.

Materials

double slit of known separation	masking tape
goggles	metre stick
holder for the double slit	metric tape measure
laser of unknown wavelength	paper screen

CAUTIONS: LIGHT FROM A LASER CAN BE HARMFUL TO THE EYE.

DO NOT LOOK DIRECTLY INTO THE LASER BEAM.

GUARD AGAINST STRAY REFLECTIONS.

CLAMP THE LASER FIRMLY IN PLACE.

WEAR EYE GOGGLES AND WORK WITH THE LIGHTS ON.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 37

WAVELENGTH OF LASER LIGHT

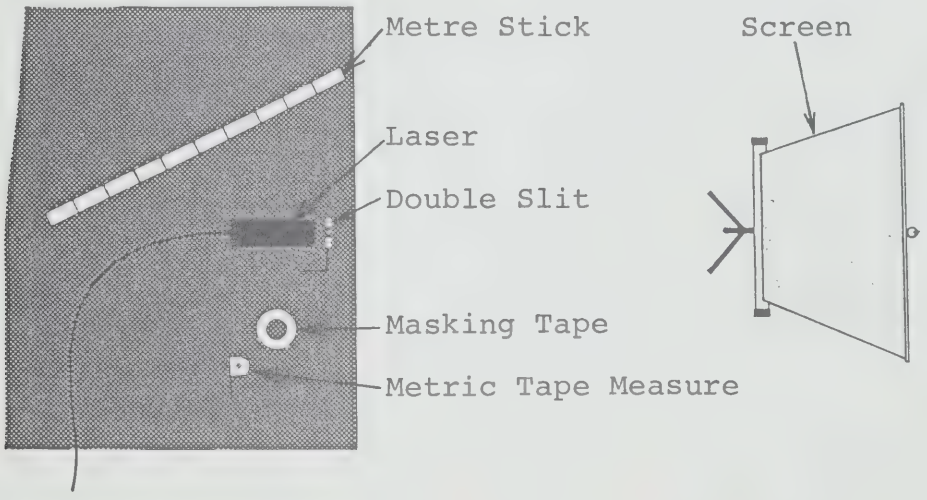
Note: Return this sheet to your examiner at the end of the test.

Method

CAUTION: CLAMP THE LASER SECURELY IN POSITION. DO NOT TURN ON THE LASER UNTIL YOU ARE READY TO TAKE MEASUREMENTS.

a. Position the screen several metres from the laser.

b. Mount the double slit close to and directly in front of the laser as shown in the diagram. (Top view)



c. Turn on the laser.

CAUTION: WEAR GOGGLES. DO NOT LOOK DIRECTLY INTO THE LASER BEAM, AND GUARD AGAINST STRAY REFLECTIONS.

d. Adjust the position of the slits to obtain a double slit interference pattern on the screen.

e. Measure on the screen the distance between the centres of a known number of minima.

f. Calculate and record the separation between the centres of adjacent minima.

g. Measure and record the distance from the double slit to the interference pattern on the screen.

Method continued

h. Obtain the slit separation from the examiner.

i. Use the relationship among the variables to calculate the wavelength of the laser light. Show all calculations.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 38

RESISTANCE OF A SERIES CIRCUIT

Notes to the Teacher

S17A
III.2.e

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

104

2. Minimum number of students: 1

A7
B3
C4

3. Prerequisite knowledge:

   a. circuit diagrams and symbols
   b. connecting an ammeter
   c. connecting a series circuit
   d. connecting a voltmeter
   e. electric current I
   f. electric potential difference V
   g. electric resistance R
   h. $R = \frac{V}{I}$
   i. resistor
   j. series connection of resistors

**
-
**

4. Preparation:

   a. Provide nichrome wire, or wire wound resistors of high power, as the resistances. Mask the colour codes.
   b. Ignore the errors due to the finite resistance of the voltmeter.
   c. Several different stations can be set up by using different resistances.

5. CAUTIONS:

   a. DO NOT USE A SOURCE EXCEEDING 24 V D.C.
   b. TO PROTECT THE METERS, CHECK THE CIRCUIT BEFORE PERMITTING STUDENTS TO CLOSE THE SWITCH.
   c. STRESS THAT THE TEMPERATURE OF THE RESISTORS SHOULD BE ALLOWED TO REACH A CONSTANT VALUE BEFORE READINGS ARE TAKEN.

LABORATORY-EXPERIMENT TEST INSTRUMENT 38

RESISTANCE OF A SERIES CIRCUIT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for an electronics firm. You have been assigned the task of assembling a circuit to determine the effective resistance of two resistors connected in series to an electric potential difference.

Materials

ammeter	2 resistors of unknown resistance
10 connecting leads	single pole single throw switch
D.C. power supply	voltmeter

CAUTION: TO PROTECT THE METERS, HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) **Under the heading "Problem" write in your own words a clear statement of the problem under investigation.**

b) **Examine the materials supplied by your examiner.**

c) **Under the heading "Diagram" draw a circuit diagram showing the proposed experiment set up.**

d) **Under the heading "Method" list in order the steps of the method you will use to solve the problem.**

e) **When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.**

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

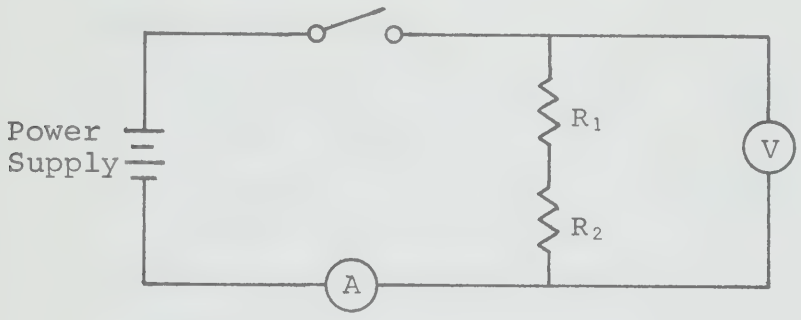
PROCEDURE SHEET 38

RESISTANCE OF A SERIES CIRCUIT

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the resistors, ammeter, switch, voltmeter, and power supply as shown in the diagram below. Do not close the switch.



CAUTION: HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

b. Close the switch. Allow sufficient time for the temperature of the resistors to stabilize.

c. Measure the electric current through the resistors and the electric potential difference across the series combination of resistors.

d. Use the electric current and the electric potential difference to determine the effective resistance of the two resistors connected in series.

e. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 39

RESISTANCE OF A PARALLEL CIRCUIT

Notes to the Teacher

S17A
III.2.e

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

104

2. Minimum number of students: 1

A7
B3
C4

3. Prerequisite knowledge:

   a. circuit diagrams and symbols
   b. connecting an ammeter
   c. connecting a series circuit
   d. connecting a voltmeter
   e. electric current I
   f. electric potential difference V
   g. electric resistance R
   h. parallel connection of resistors
   i. $R = \frac{V}{I}$
   j. resistor

**
-
**

4. Preparation:

   a. Provide nichrome wire, or wire wound resistors of high power, as the resistances. Mask the colour codes.
   b. Ignore the errors due to the finite resistance of the voltmeter.
   c. Several different stations can be set up by using different resistances.

5. CAUTIONS:

   a. DO NOT USE A SOURCE EXCEEDING 24 V D.C.
   b. TO PROTECT THE METERS, CHECK THE CIRCUIT BEFORE PERMITTING STUDENTS TO CLOSE THE SWITCH.
   c. STRESS THAT THE TEMPERATURE OF THE RESISTORS SHOULD BE ALLOWED TO REACH A CONSTANT VALUE BEFORE READINGS ARE TAKEN.

LABORATORY-EXPERIMENT TEST INSTRUMENT 39

RESISTANCE OF A PARALLEL CIRCUIT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for an electronics firm. You have been assigned the task of assembling a circuit to determine the effective resistance of two resistors connected in parallel to an electric potential difference.

Materials

ammeter	2 resistors of unknown resistance
10 connecting leads	single pole single throw switch
D.C. power supply	voltmeter

CAUTION: TO PROTECT THE METERS, HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

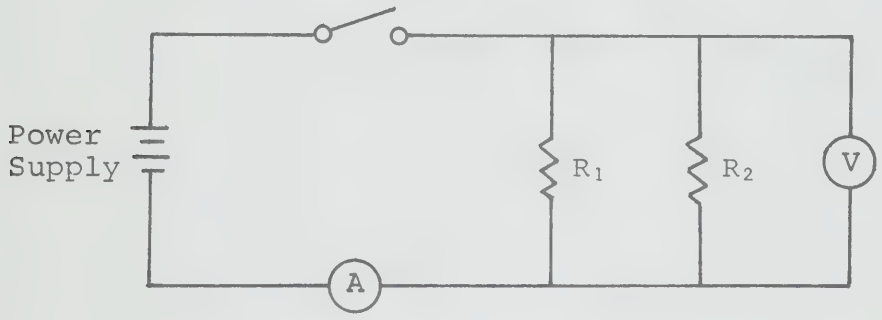
PROCEDURE SHEET 39

RESISTANCE OF A PARALLEL CIRCUIT

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the resistors, ammeter, switch, voltmeter, and power supply as shown in the diagram. Do not close the switch.



CAUTION: HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CONTINUING.

b. Close the switch. Allow sufficient time for the temperature of the resistors to stabilize.

c. Measure the total electric current through the resistors and the electric potential difference across the combination of resistors.

d. Use the total electric current and the electric potential difference to determine the effective resistance of the two resistors connected in parallel.

e. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 40

RESISTANCE OF A LOAD

Notes to the Teacher

S17A
III.2.e

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

104

2. Minimum number of students: 1

A7
B3
C4

3. Prerequisite knowledge:

   a. circuit diagrams and symbols
   b. connecting an ammeter
   c. connecting a series circuit
   d. connecting a voltmeter
   e. electric current I
   f. electric potential difference V
   g. electric resistance R
   h. load
   i. $R = \frac{V}{I}$
   j. resistor

**
-
**

4. Preparation:

   a. Provide nichrome wire, or a wire wound resistor of high power, as the resistance. Mask the colour codes.
   b. Ignore the error due to the finite resistance of the voltmeter.
   c. Several stations can be set up around the room by using different resistances.

5. CAUTIONS:

   a. DO NOT USE A SOURCE EXCEEDING 24 V D.C.
   b. TO PROTECT THE METERS, CHECK THE CIRCUIT BEFORE PERMITTING STUDENTS TO CLOSE THE SWITCH.
   c. STRESS THAT THE TEMPERATURE OF THE RESISTOR SHOULD BE ALLOWED TO REACH A CONSTANT VALUE BEFORE READINGS ARE TAKEN.

LABORATORY-EXPERIMENT TEST INSTRUMENT 40

RESISTANCE OF A LOAD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for an electronics firm. You have been assigned the task of assembling a circuit and determining the resistance of a load without using an ohmmeter.

Materials

ammeter	resistor of unknown resistance called the load
8 connecting leads	single pole single throw switch
D.C. power supply	voltmeter

CAUTION: TO PROTECT THE METERS, HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

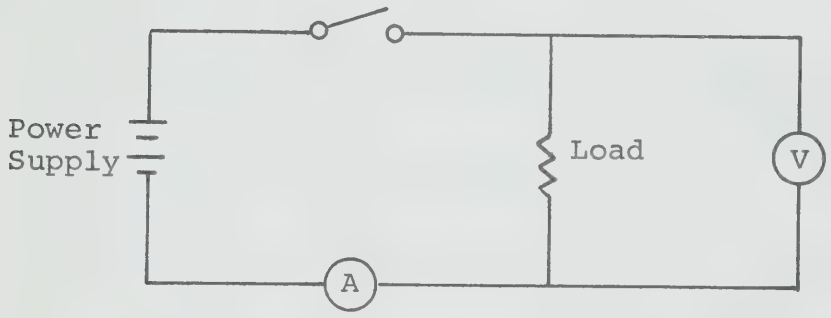
PROCEDURE SHEET 40

RESISTANCE OF A LOAD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the load, ammeter, switch, voltmeter, and power supply as shown in the diagram. Do not close the switch.



CAUTION: HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

b. Close the switch. Allow sufficient time for the temperature of the load to stabilize.

c. Measure the electric current through the load and the electric potential difference across the load.

d. Use the electric current and the electric potential difference to determine the resistance of the load.

e. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 41

RESISTORS IN A SEALED MYSTERY BOX: AMMETER-VOLTMETER METHOD

Notes to the Teacher

S17A
III.2.g

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

104

2. Minimum number of students: 1

A11
B3
C4
D3
E2

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-
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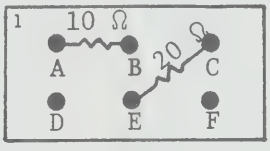
3. Prerequisite knowledge:

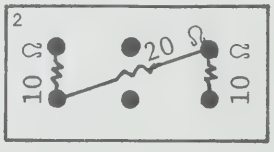
   a. circuit diagrams and symbols
   b. connecting meters
   c. connecting simple circuits
   d. electric current I
   e. electric potential difference V
   f. electric resistance R
   g. incomplete circuit
   h. $R = \frac{V}{I}$
   i. resistors in series
   j. resistors in parallel

4. Preparation:

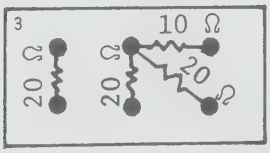
   a. Sealed mystery boxes, similar to the following, can be constructed using wood, masonite, stove bolts, connecting wires, and precision resistors.

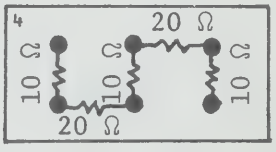
EASY



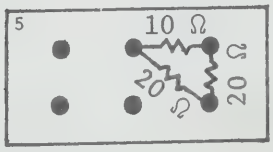


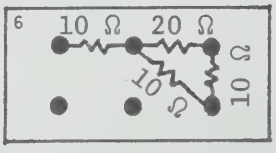
MEDIUM





VERY DIFFICULT





   b. Some boxes should have no back cover so that students can practice prior to the test.

Notes to the Teacher continued

4. c. Number the sealed boxes and keep the record of the contents secure.

   d. A box may have more than one acceptable solution. Do not set an impossible task and provide students with an ohmmeter for the more complex circuits.

5. Circuits containing resistors connected in parallel are very difficult to analyze. Use high precision resistors for these circuits and keep them simple.

6. Do not replace resistors with conducting wires when ammeters and voltmeters are used to analyze the circuit.

7. CAUTIONS:

   a. DO NOT USE A SOURCE EXCEEDING 24 V D.C.

   b. TO PROTECT THE METERS, CHECK THE FIRST CIRCUIT BEFORE PERMITTING STUDENTS TO CLOSE THE SWITCH.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 41

RESISTORS IN A SEALED MYSTERY BOX:

AMMETER-VOLTMETER METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are applying for a job testing circuits with an electronics firm. In order to be accepted for the job, you must determine the contents of a sealed mystery box and submit a circuit diagram showing the location and size of resistors contained in the box.

Materials

ammeter	sealed resistance mystery box
connecting leads	single pole single throw switch
6 V D.C. battery	voltmeter

CAUTION: TO PROTECT THE METERS, HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

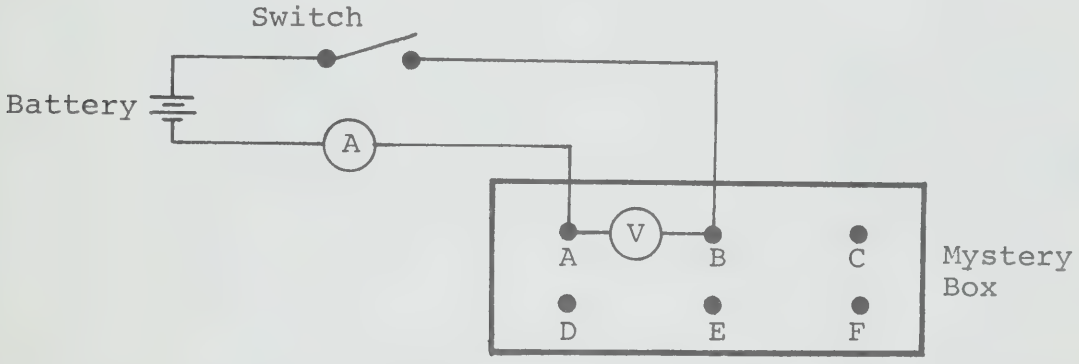
PROCEDURE SHEET 41

RESISTORS IN A SEALED MYSTERY BOX: AMMETER-VOLTMETER METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the battery, ammeter, voltmeter, and switch to the terminals labelled A and B of the resistance mystery box as shown in the diagram below. Do not close the switch.



CAUTION: HAVE THE EXAMINER CHECK THE FIRST CIRCUIT BEFORE CONTINUING.

b. Close the switch. Allow sufficient time for the temperature of the resistors to stabilize.

c. Measure the current through AB and the electric potential difference across AB.

d. Use the current and the electric potential difference to determine the resistance between A and B.

e. Repeat steps (a) to (d) for all possible pairs of terminals of the resistance mystery box.

f. From your results, determine the position of the resistors in the mystery box and draw the associated schematic diagram.

g. Determine the possible values of the resistors in the mystery box and place these values on the schematic diagram.

h. When you have finished, submit this procedure, the schematic diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 42

RESISTORS IN A SEALED MYSTERY BOX: OHMMETER METHOD

Notes to the Teacher

S17A
III.2.g

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

104

2. Minimum number of students: 1

A11
B3
C4
D3
E2

3. Prerequisite knowledge:

   a. circuit diagrams and symbols
   b. connecting meters
   c. connecting simple circuits
   d. electric resistance *R*
   e. incomplete circuit
   f. resistors in series
   g. resistors in parallel
   h. ohmmeter

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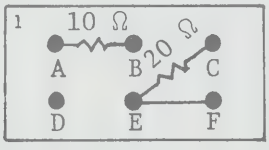
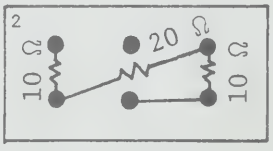
4. Preparation:

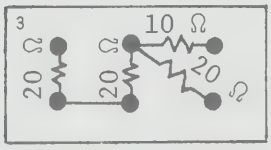
   a. Sealed mystery boxes, similar to the following, can be constructed using wood, masonite, stove bolts, connecting wires, and precision resistors.

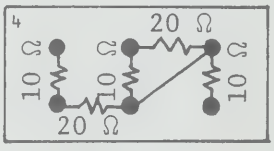
EASY



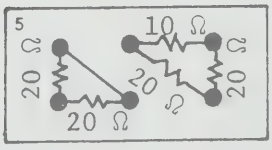


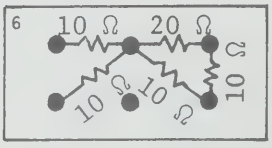
MEDIUM





VERY DIFFICULT





   b. Some boxes should have no back cover so that students can practice prior to the test.

   c. Number the sealed boxes, and keep the record of the contents secure.

   d. Some boxes may have more than one acceptable solution.

Notes to the Teacher continued

4. e. Do not set an impossible task.

5. CAUTIONS:

   a. DO NOT USE A SOURCE EXCEEDING 24 V D.C.

   b. TO PROTECT THE METERS, CHECK THE FIRST CIRCUIT BEFORE PERMITTING STUDENTS TO CLOSE THE SWITCH.

   c. CIRCUITS CONTAINING RESISTORS CONNECTED IN PARALLEL ARE VERY DIFFICULT TO ANALYZE. USE HIGH PRECISION RESISTORS FOR THESE CIRCUITS AND KEEP THEM REASONABLY SIMPLE.

LABORATORY-EXPERIMENT TEST INSTRUMENT 42

RESISTORS IN A SEALED MYSTERY BOX: OHMMETER METHOD

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are applying for a job testing circuits with an electronics firm. In order to be accepted for the job, you must determine the contents of a sealed mystery box and submit a circuit diagram showing the location and size of resistors contained in the box, as well as the location of any internal connecting wires.

Materials

connecting leads	sealed resistance mystery box
6 V D.C. battery	single pole single throw switch
ohmmeter	

CAUTION: TO PROTECT THE OHMMETER, HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) **Under the heading "Problem" write in your own words a clear statement of the problem under investigation.**

b) **Examine the materials supplied by your examiner.**

c) **Under the heading "Diagram" draw a circuit diagram showing the proposed experiment set up.**

d) **Under the heading "Method" list in order the steps of the method you will use to solve the problem.**

e) **When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.**

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

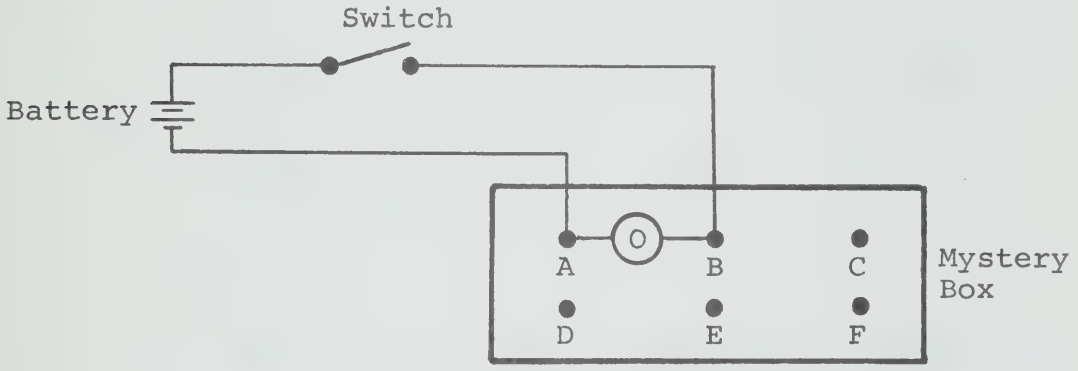
PROCEDURE SHEET 42

RESISTORS IN A SEALED MYSTERY BOX: OHMMETER METHOD

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the battery, ohmmeter, and open switch to the terminals labelled A and B of the resistance mystery box as shown in the diagram.



b. Close the switch. Allow sufficient time for the temperature of the resistors to stabilize.

c. Determine the resistance between A and B.

d. Repeat steps (a) to (c) for all possible pairs of terminals of the resistance mystery box.

e. From your results, determine the position of the resistors in the mystery box and draw the associated schematic diagram.

f. Determine the possible values of the resistors in the mystery box and place these values on the schematic diagram, as well as the location of any internal connecting wires.

g. When you have finished, submit this procedure sheet, the schematic diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 43

POWER DISSIPATED IN A PARALLEL CIRCUIT

Notes to the Teacher

S17A
III.2.h

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

105

2. Minimum number of students: 1

A7
A8
B3
D1
D3
**
-
**

3. Prerequisite knowledge:

   a. circuit diagrams and symbols
   b. connecting voltmeters and ammeters
   c. electric current I
   d. electric potential difference V
   e. electric power P
   f. parallel connection of resistors
   g. $P = IV$
   h. resistor

4. Preparation:

   a. Provide nichrome wire, or wire wound resistors of high power, as the resistances. Mask the colour codes.
   b. Ignore the error due to the finite resistance of the voltmeter.
   c. Several different stations can be set up by using different resistances.
   d. Tell the students the electric potential difference you want them to use.

5. CAUTIONS:

   a. DO NOT USE A SOURCE EXCEEDING 24 V D.C.
   b. TO PROTECT THE METERS, CHECK THE CIRCUIT BEFORE PERMITTING STUDENTS TO CLOSE THE SWITCH.
   c. STRESS THAT THE TEMPERATURE OF THE RESISTORS SHOULD BE ALLOWED TO REACH A CONSTANT VALUE BEFORE READINGS ARE TAKEN.

LABORATORY-EXPERIMENT TEST INSTRUMENT 43

POWER DISSIPATED IN A PARALLEL CIRCUIT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for an electronics firm. You have been assigned the task of determining the power dissipated in the combination of two resistors connected in parallel to a given electric potential difference.

Materials

ammeter	2 resistors of unknown resistance
10 connecting leads	single pole single throw switch
D.C. power supply	voltmeter

CAUTION: TO PROTECT THE METERS, HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate heading.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a circuit diagram showing the proposed connection of the power supply, ammeter, voltmeter, resistors, and switch.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

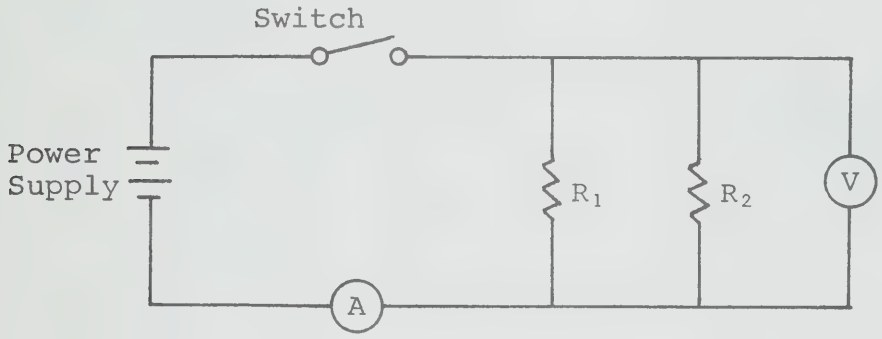
PROCEDURE SHEET 43

POWER DISSIPATED IN A PARALLEL CIRCUIT

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the resistors, ammeter, open switch, voltmeter, and power supply as shown in the diagram.



CAUTION: HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CONTINUING.

b. Close the switch. Allow sufficient time for the temperature of the resistors to stabilize.

c. Measure the total current through the resistors and the electric potential difference across the parallel combination of resistors.

d. Use the total current and the electric potential difference to determine the power dissipated in the two resistors connected in parallel.

e. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 44

POWER DISSIPATED IN A SERIES CIRCUIT

Notes to the Teacher

S17A
III.2.h

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

105

2. Minimum number of students: 1

A7
A8
B3
D1
D3

3. Prerequisite knowledge:

   a. circuit diagrams and symbols
   b. series connection of resistors
   c. electric current I
   d. electric potential difference V
   e. electric power P
   f. connecting ammeter and voltmeter
   g. $P = IV$
   h. resistor

**
-
**

4. Preparation:

   a. Provide nichrome wire, or wire wound resistors of high power, as the resistances. Mask the colour codes.
   b. Ignore the error due to the finite resistance of the voltmeter.
   c. Several different stations can be set up by using different resistances.
   d. Tell the students what electric potential difference you want them to use.

5. CAUTIONS:

   a. DO NOT USE A SOURCE EXCEEDING 24 V D.C.
   b. TO PROTECT THE METERS, CHECK THE CIRCUIT BEFORE PERMITTING STUDENTS TO CLOSE THE SWITCH.
   c. STRESS THAT THE TEMPERATURE OF THE RESISTORS SHOULD BE ALLOWED TO REACH A CONSTANT VALUE BEFORE READINGS ARE TAKEN.

LABORATORY-EXPERIMENT TEST INSTRUMENT 44

POWER DISSIPATED IN A SERIES CIRCUIT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for an electronics firm. You have been assigned the task of determining the power dissipated in the combination of two resistors connected in series to a given electric potential difference.

Materials

ammeter	2 resistors of unknown resistances
8 connecting leads	switch
D.C. power supply	voltmeter

CAUTION: TO PROTECT THE METERS, HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a circuit diagram showing the proposed connection of the power supply, ammeter, voltmeter, resistors, and switch.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

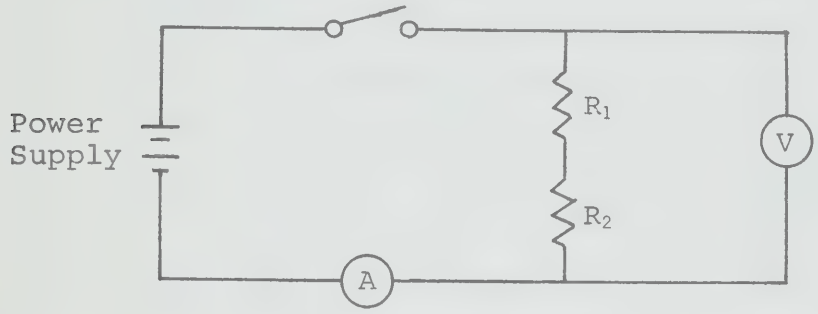
PROCEDURE SHEET 44

POWER DISSIPATED IN A SERIES CIRCUIT

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the resistors, ammeter, open switch, voltmeter, and the power supply as shown in the diagram.



CAUTION: HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CONTINUING.

b. Close the switch. Allow sufficient time for the temperature of the resistors to stabilize.

c. Measure the current through the resistors, and the electric potential difference across the combination of resistors.

d. Use the current and the electric potential difference to determine the power dissipated in the two resistors connected in series.

e. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 45

POWER DISSIPATED BY AN INCANDESCENT LIGHT BULB

Notes to the Teacher

S17A
III.2.h

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

105

2. Minimum number of students: 1

A7
A8
B3
D1
D3

3. Prerequisite knowledge:

   a. circuit diagrams and symbols
   b. connecting a potentiometer to a power supply
   c. connecting a simple circuit containing a load
   d. connecting voltmeters and ammeters
   e. electric current I
   f. electric potential difference V
   g. electric power P
   h. $P = IV$

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4. Preparation:

   a. Use incandescent light bulbs rated at 24 V or less. 12 V miniature light bulbs work well.
   b. Several stations can be set up around the room by using different light bulbs. Number the light bulbs for identification.
   c. Tell the students the three electric potential differences you want them to use. Space has been provided in the problem statement for this purpose.

5. CAUTIONS:

   a. DO NOT USE A SOURCE EXCEEDING 24 V D.C.
   b. TO PROTECT THE METERS, CHECK THE CIRCUIT BEFORE PERMITTING STUDENTS TO CLOSE THE SWITCH.
   c. STRESS THAT THE VOLTAGES USED MUST NOT EXCEED THE VOLTAGE RATING OF THE BULB.
   d. THE BULBS SHOULD BE ALLOWED TO REACH A CONSTANT TEMPERATURE BEFORE READINGS ARE TAKEN.

LABORATORY-EXPERIMENT TEST INSTRUMENT 45

POWER DISSIPATED BY AN INCANDESCENT LIGHT BULB

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for a company that manufactures electric light bulbs. You have been assigned the task of determining the power of a light bulb for three different values of electric potential. The three values of electric potential difference are ___ V, ____ V, and ____ V.

Materials

ammeter
D.C. power supply
and potentiometer
OR
variable voltage
D.C. power supply

8 connecting leads
incandescent light bulb
switch
voltmeter

CAUTION: TO PROTECT THE METERS, HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CLOSING THE SWITCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a circuit diagram showing the proposed connection of the power supply, ammeter, voltmeter, resistors, and switch.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

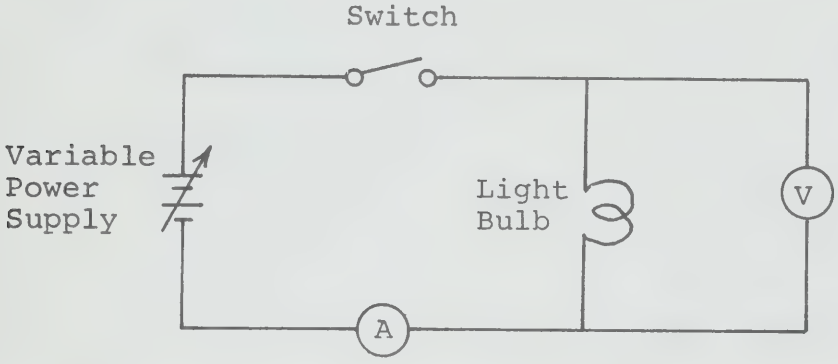
PROCEDURE SHEET 45

POWER DISSIPATED BY AN INCANDESCENT LIGHT BULB

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the variable power supply to the open switch, light bulb, ammeter and voltmeter as shown in the diagram below.



CAUTION: HAVE THE EXAMINER CHECK THE CIRCUIT BEFORE CONTINUING.

b. Close the switch. Allow sufficient time for the temperature of the light bulb to stabilize.

c. Measure the electric current through the light bulb for three different values of electric potential difference.

d. Use the electric current and the electric potential difference specified by the examiner to determine the power dissipated in the incandescent light bulb for the three different values of electric potential difference.

e. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 46

SPEED OF SOUND IN AN AIR COLUMN CLOSED AT ONE END

Notes to the Teacher

S17A
II.2.b

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (25 min)

145

2. Minimum number of students: 2

A7
B3
C4
D3

3. Prerequisite knowledge:

   a. air columns closed at one end
   b. constructive and destructive interference
   c. end effect
   d. frequency f
   e. $L = \frac{n}{4}\lambda$, where $n = 1, 3, 5$, etc.
   f. resonance
   g. resonant length L
   h. speed of sound v
   i. $v = f\lambda$
   j. wavelength λ

**
-
**

4. Preparation:

   a. Several stations can be set up by using tuning forks of different frequencies.
   b. The end effect can cause a significant error.
   c. To compensate for the end effect, measure the first and second resonant lengths and subtract. The difference is equal to $\frac{1}{2}\lambda$.
   d. Frequencies between 512 Hz and 1024 Hz produce excellent results.
   e. To compensate for the end effect, the resonance tube should be between 27 cm and 54 cm long for frequencies between 512 Hz and 1024 Hz.
   f. Harmonics may confuse the students.
   g. Two procedure sheets have been included: one compensates for the end effect; the other does not.
   h. To correct for the effect of temperature on the speed of sound, use the relationship

$$V_T = 332 \text{ m/s} + T[0.6 \text{ m/(s}\cdot^\circ\text{C)}]$$

Notes to the Teacher continued

4. i. The correction for the end effect is about 0.6 times the tube radius, which is added to the resonant length.

   j. Have the students activate the tuning fork using a rubber stopper to prevent damage to the prongs.

5. CAUTION:

   A GLASS RESONANCE TUBE CAN SHATTER IF THE VIBRATING PRONGS OF A TUNING FORK COME IN CONTACT WITH IT.

LABORATORY-EXPERIMENT TEST INSTRUMENT 46

SPEED OF SOUND IN AN AIR COLUMN CLOSED AT ONE END

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Sometimes physicists use an indirect method to determine the size of an object or physical quantity. Your problem is to design and implement a method to determine the speed of sound in an air column closed at one end.

Materials

adjustable clamp
metre stick
retort stand
tall glass cylinder
tube open at both ends
tuning fork of a specified frequency
tuning fork activator (rubber stopper)
water

CAUTION: A GLASS RESONANCE TUBE CAN SHATTER IF THE VIBRATING PRONGS OF A TUNING FORK COME IN CONTACT WITH IT.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 46

SPEED OF SOUND IN AN AIR COLUMN CLOSED AT ONE END

Note: Return this sheet to your examiner at the end of the test.

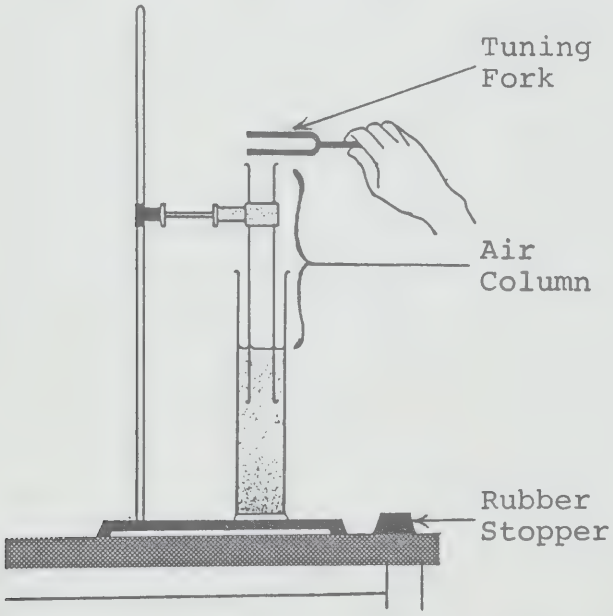
Method A

a. Fill the cylinder to within 5 cm of the top with water.

b. Attach the tube to the retort stand using the adjustable clamp.

c. Lower one end of the tube into the water.

d. Sound the tuning fork and hold it directly above and close to the open end of the tube as shown in the diagram.



e. Raise or lower the tube in the water to find the shortest length of air column that resonates with the tuning fork.

f. Measure the first resonant length of the air column.

g. Determine the wavelength of the sound wave. Show all calculations.

h. Determine the speed of sound in the air column. Show all calculations.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

PROCEDURE SHEET 46

SPEED OF SOUND IN AN AIR COLUMN CLOSED AT ONE END

Note: Return this sheet to your examiner at the end of the test.

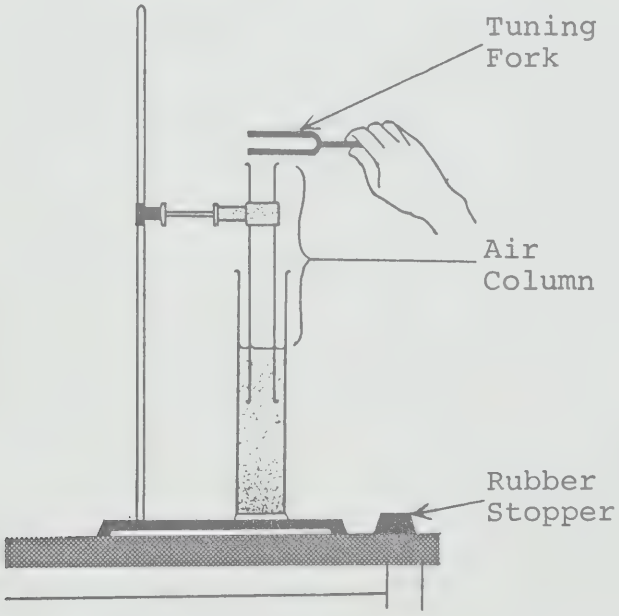
Method B

a. Fill the cylinder to within 5 cm of the top with water.

b. Attach the tube to the retort stand using the adjustable clamp.

c. Lower one end of the tube into the water.

d. Sound the tuning fork and hold it directly above and close to the open end of the tube as shown in the diagram.



e. Raise or lower the tube in the water to find the shortest length of air column that resonates with the tuning fork.

f. Measure the first resonant length of the air column.

g. Slowly raise the tube in the water to find the second length of air column that resonates with the tuning fork.

h. Measure this length of the air column.

i. Determine the wavelength of the sound wave. Show all calculations.

SPEED OF SOUND IN AN AIR COLUMN CLOSED AT ONE END

Method B continued

j. Determine the speed of sound in the air column. Show all calculations.

k. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 47

SPEED OF SOUND IN AN AIR COLUMN OPEN AT BOTH ENDS

Notes to the Teacher

S17A
II.2.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

145

2. Minimum number of students: 2

A7
B3
C4
D3

3. Prerequisite knowledge:

   a. air columns open at both ends
   b. constructive and destructive interference
   c. end effect
   d. frequency of sound f
   e. $L = \frac{n}{4}\lambda$, where n = 2, 4, 6, etc.
   f. resonance
   g. resonant length L
   h. speed of sound v
   i. $v = f\lambda$
   j. wavelength λ

**
-
**

4. Preparation:

   a. Several stations can be set up by using tuning forks of different frequencies.
   b. The end effect can cause significant errors.
   c. Frequencies of 512 Hz or above yield better results than lower frequencies.
   d. Harmonics may confuse the students.
   e. The longer resonance tube should be between 30 cm and 60 cm for frequencies between 512 Hz and 1024 Hz.
   f. The correction for the end effect is about 0.6 times the tube radius which is added to the resonant length.
   g. To correct for the effect of temperature on the speed of sound, use the relationship:

$$V_T = 332 \text{ m/s} + T[0.6 \text{ m/(s}\cdot^\circ\text{C)}]$$

   h. Have the students activate the tuning fork using a rubber stopper to prevent damage to the prongs.

5. CAUTION:

   A GLASS RESONANCE TUBE CAN SHATTER IF THE VIBRATING PRONGS OF A TUNING FORK COME IN CONTACT WITH IT.

LABORATORY-EXPERIMENT TEST INSTRUMENT 47

SPEED OF SOUND IN AN AIR COLUMN OPEN AT BOTH ENDS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Sometimes physicists use an indirect method to determine the size of an object or physical quantity. Your problem is to design and implement a method to indirectly determine the speed of sound in an air column open at both ends.

Materials

2 adjustable clamps	small tube open at both ends
metre stick	large tube open at both ends
2 retort stands	tuning fork of specified frequency
	tuning fork activator (rubber stopper)

CAUTION: A GLASS RESONANCE TUBE CAN SHATTER IF THE VIBRATING PRONGS OF A TUNING FORK COME IN CONTACT WITH IT.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 47

SPEED OF SOUND IN AN AIR COLUMN OPEN AT BOTH ENDS

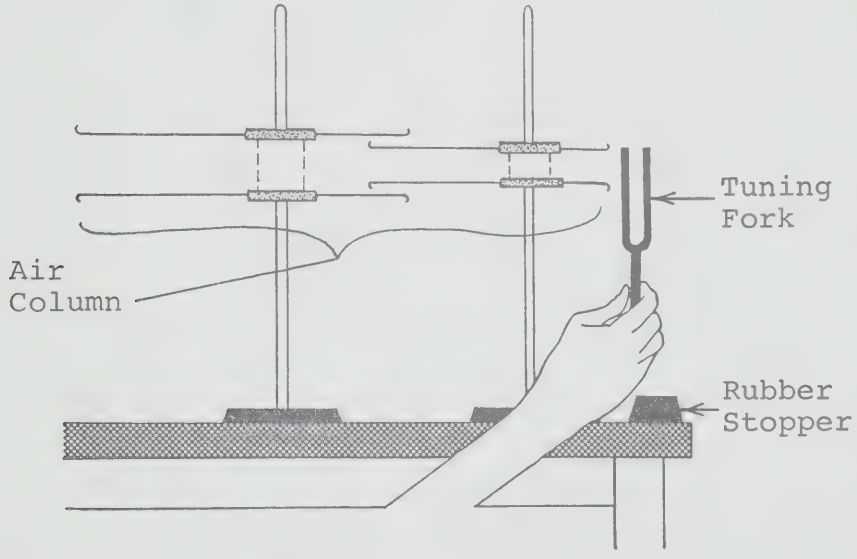
Note: Return this sheet to your examiner at the end of the test.

Method

a. Attach a tube open at both ends horizontally to a retort stand using the adjustable clamp.

b. Attach another tube horizontally to another retort stand.

c. Insert the smaller tube inside the larger, as shown in the diagram.



d. Sound the tuning fork and hold it close to the open end of one of the tubes.

e. Slowly change the length of the open tube to find the shortest length of air column that resonates with the tuning fork.

f. Measure the length of the air column.

g. Determine the wavelength of the sound waves. Show all calculations.

h. Determine the speed of sound in the air column. Show all calculations.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 48

FREQUENCY OF A TUNING FORK

Notes to the Teacher

S17A
II.2.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

145

2. Minimum number of students: 2

A7
B3
C4
D3

3. Prerequisite knowledge:

   a. air columns closed at one end
   b. constructive and destructive interference
   c. end effect
   d. frequency of sound f
   e. $L = \frac{n}{4}\lambda$, where $n = 1, 3, 5$, etc.
   f. resonance
   g. resonant length L
   h. speed of sound v
   i. $v = f\lambda$
   j. wavelength λ
   k. temperature T
   l. $V_T = V_{0°C} + T[0.6\ \text{m/(s}\cdot°\text{C)}]$

**
-
**

4. Preparation:

   a. Several stations can be set up by using tuning forks of different frequencies.
   b. The end effect can cause a significant error.
   c. To compensate for the end effect, measure the first and second resonant lengths and subtract. The difference is equal to $\frac{1}{2}\lambda$.
   d. Frequencies between 512 Hz and 1024 Hz produce excellent results.
   e. To compensate for the end effect, the resonance tube should be between 27 cm and 54 cm long for frequencies between 512 Hz and 1024 Hz.
   f. Harmonics may confuse the students.
   g. Two procedure sheets have been included: one does not compensate for end effect; the other does.
   h. Have students activate the tuning fork using a rubber stopper to prevent damage to the prongs.
   i. The correction for end effect is about 0.6 times the tube radius which is added to the resonant length.

LABORATORY-EXPERIMENT TEST INSTRUMENT 48

FREQUENCY OF A TUNING FORK

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Sometimes physicists use an indirect method to determine the size of an object or physical quantity. Your problem is to design and implement a method to indirectly determine the frequency of a tuning fork using the speed of sound in air.

Materials

adjustable clamp	tube open at both ends
Celsius thermometer	tuning fork of unknown frequency
metre stick	tall glass cylinder
retort stand	water

CAUTION: A GLASS RESONANCE TUBE CAN SHATTER IF THE VIBRATING PRONGS OF A TUNING FORK COME IN CONTACT WITH IT.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 48

FREQUENCY OF A TUNING FORK

Note: Return this sheet to your examiner at the end of the test.

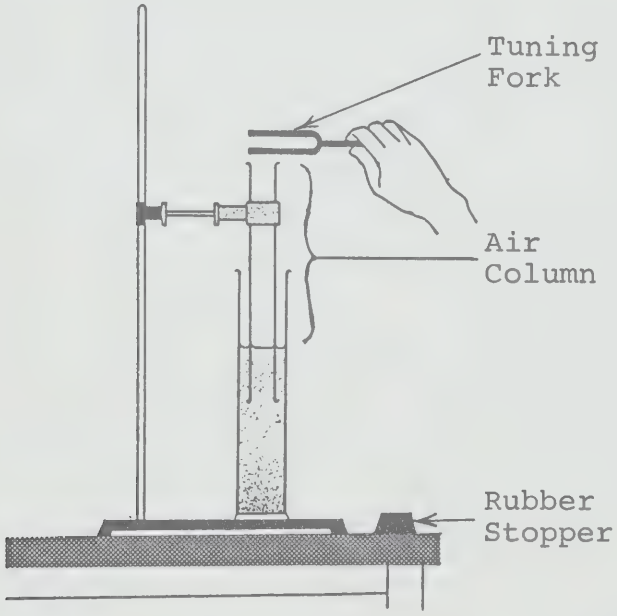
Method A

a. Fill the cylinder to within 5 cm of the top with water.

b. Attach the tube to the retort stand using the adjustable clamp.

c. Lower one end of the tube into the water.

d. Sound the tuning fork and hold it directly above and close to the open end of the tube as shown in the diagram.



e. Raise or lower the tube in the water to find the shortest length of air column that resonates with the tuning fork.

f. Measure the first resonant length of the air column.

g. Determine the wavelength of the sound waves. Show all calculations.

Method A continued

h. Read room temperature. Use the speed of sound at 0°C (332 m/s) and the change in speed with temperature [0.6 m/(s.°C)] to calculate the speed of sound in the air column. Show all calculations.

i. Determine the frequency of the tuning fork. Show all calculations.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

PROCEDURE SHEET 48

FREQUENCY OF A TUNING FORK

Note: Return this sheet to your examiner at the end of the test.

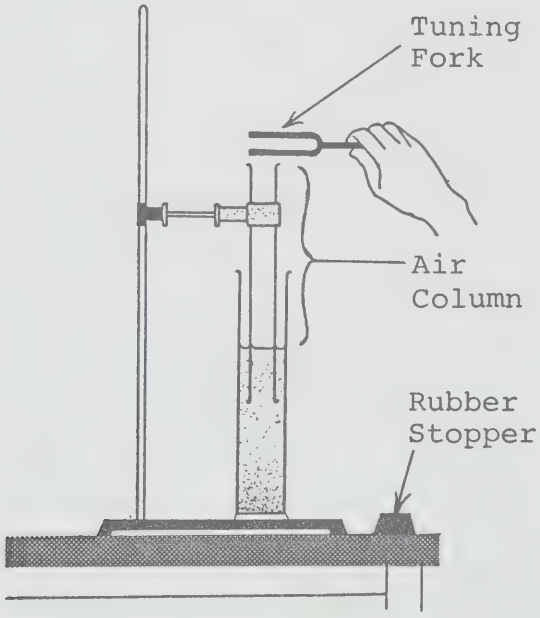
Method B

a. Fill the cylinder to within 5 cm of the top with water.

b. Attach the tube to the retort stand using the adjustable clamp.

c. Lower one end of the tube into the water.

d. Sound the tuning fork and hold it directly above and close to the open end of the tube as shown in the diagram.



e. Raise or lower the tube in the water to find the shortest length of air column that resonates with the tuning fork.

f. Measure the first resonant length of the air column.

g. Slowly raise the tube in the water to find the second length of air column that resonates with the tuning fork.

h. Measure the second resonant length of the air column.

Method B continued

i. Determine the wavelength of the sound waves. Show all calculations.

j. Read room temperature. Use the speed of sound at 0°C (332 m/s) and the change in speed with temperature [0.6 m/(s.°C)] to calculate the speed of sound in the air column. Show all calculations.

k. Determine the frequency of the tuning fork. Show all calculations.

l. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 49

THE ARRANGEMENT OF MAGNETS IN A SEALED MYSTERY BOX

Notes to the Teacher

S17A
III.3.a

1. Suggested schedule: Part A - Experiment Design (10 min)
   Part B - Experiment Report (20 min)

202

2. Minimum number of students: 1

A7
A11
B2

3. Prerequisite knowledge:

   a. law of magnetic poles
   b. magnetic field lines
   c. N-pole
   d. polarity
   e. S-pole
   f. use of a magnetic compass

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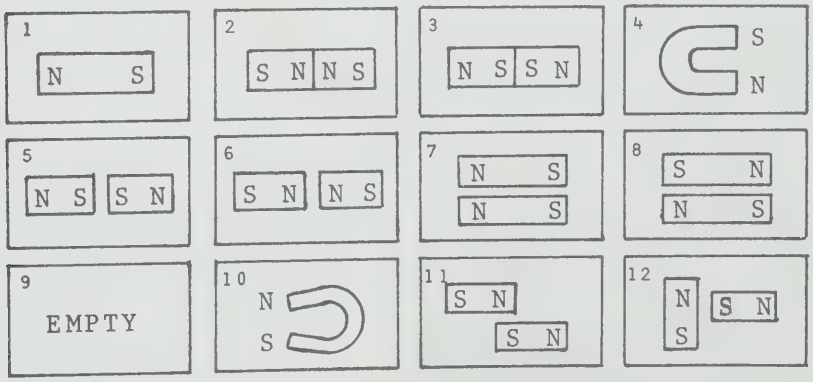
4. Preparation:

   a. Sealed mystery boxes can be constructed by embedding the magnets in styrofoam and enclosing in hardboard or thin cardboard.

   b. Adjust pairs of magnets for the best spacing before sealing the mystery boxes.

   c. Disassemble after use and store the magnets with keepers to prevent the magnets from losing their magnetism.

   d. Some designs which can be used are shown below.



Notes to the Teacher continued

4. e. Paint the surface of the masonite or cardboard white to facilitate easy viewing.

   f. If the sealed mystery boxes are numbered and the teacher takes care to ensure that the orientation of the magnet(s) remain secure, students can work at this lab test when convenient and the test itself may be administered over a period of several days.

   g. Check the polarity of the compass before use.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 49

THE ARRANGEMENT OF MAGNETS IN A SEALED MYSTERY BOX

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Your problem is to determine the location, arrangement, and polarity of the magnet(s) inside a sealed mystery box, and to draw a diagram showing the location of the box identification number, and the arrangement and polarity of the magnet(s) inside the box.

Materials

container of iron filings
magnetic compass
sealed magnetic mystery box

CAUTION: A MAGNET CAN DAMAGE A NON-DIGITAL WRIST WATCH. DO NOT BRING THE MAGNET NEAR YOUR WRIST WATCH.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

d) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure" or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

d) When you have finished "Part B - Experiment Report" submit the diagram and the answer sheet to the examiner.

PROCEDURE SHEET 49

THE ARRANGEMENT OF MAGNETS IN A SEALED MYSTERY BOX

Note: Return this sheet to your examiner at the end of the test.

Method

a. Orient the sealed mystery box so that its identification number is in the upper left corner.

b. Place a sheet of white paper with the edges folded upward over the box.

c. Sprinkle iron filings evenly over the surface of the paper while tapping it lightly.

d. Use the magnetic compass to determine the location and polarity of the poles of the magnet(s) inside the box.

e. Draw an outline of the box on a piece of paper. Show the location of the box identification number. Draw the arrangement and polarity of the magnet(s) inside the box. Do not draw the field lines.

f. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 50

MAKING A PERMANENT MAGNET USING A COIL

Notes to the Teacher

S17A
III.3.a

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (15 min)

203

2. Minimum number of students: 1

A7

3. Prerequisite knowledge:

   a. coil or helix
   b. connecting a simple circuit
   c. law of magnetic poles
   d. left hand rule for a coil or helix
   e. magnetic field lines
   f. magnetic induction
   g. N-pole
   h. polarity
   i. S-pole
   j. use of a magnetic compass

4. Preparation:

   a. Demagnetize the magnetic material by heating it in the flame of a Bunsen burner.
   b. Mark one end of the magnetic material N.
   c. Provide a helix that can be connected to a battery to produce an electromagnet. Do not provide a permanent magnet.
   d. Choose a magnetic material which will retain its magnetism such as a large cement nail or steel knitting needles. Avoid soft iron.
   e. A fairly large current is required to magnetize the nail. Use a 6 V battery.

5. CAUTION:

   A STRONG MAGNET CAN DAMAGE A NON-DIGITAL WRIST WATCH. KEEP WRIST WATCHES AWAY FROM MAGNETS.

LABORATORY-EXPERIMENT
TEST INSTRUMENT 50

MAKING A PERMANENT MAGNET USING A COIL

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working for a company that makes permanent magnets. The foreman has asked you to make a magnetic material into a magnet such that the end marked N is a north seeking pole.

Materials

coil
magnetic material with one end marked N
6 V battery
switch

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a circuit diagram showing the connected battery, coil and switch, the electrical polarity of the battery, and the magnetic polarity of the coil.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure" or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

d) When you have finished "Part B - Experiment Report" submit the magnetized material and the report to your examiner.

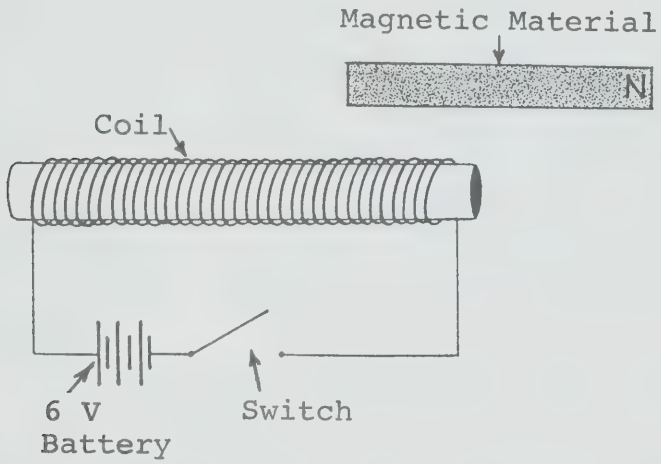
PROCEDURE SHEET 50

MAKING A PERMANENT MAGNET USING A COIL

Note: Return this sheet to your examiner at the end of the test.

Method

a. Connect the coil and open switch in series with the battery as shown in the diagram.



b. Draw a circuit diagram showing the magnetic polarity of the coil when the switch is closed.

c. Insert the magnetic material inside the coil with the end marked N pointing toward the N-pole of the coil.

d. Close the switch for several seconds. Tap the magnetic material while inside the coil.

e. Open the switch and then remove the magnetic material.

f. When you have finished, submit the magnetized material, this procedure sheet, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 51

HEIGHT OF A DISTANT OBJECT USING A PINHOLE CAMERA

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (20 min)

258

2. Minimum number of students: 1

A8
B3
C4
D3

3. Prerequisite knowledge:

   a. distance from pinhole to image d_i

   b. distance from pinhole to object d_o

   c. height of image h_i

   d. height of object h_o

   e. $h_o = h_i \frac{d_o}{d_i}$

   f. parts of a pinhole camera

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**

4. Preparation:

   a. Prevent students from directly measuring the height of the object.

   b. Give the distance from the pinhole camera to the object in cm. Record this distance in the space provided in the problem statement.

   c. Assign different students different objects to measure.

   d. Make sure the objects assigned are within the range of the pinhole camera.

   e. Specify an object large enough to produce a measurable image.

   f. A suitable object can be made by cutting an opening in a cardboard box, covering the opening with wax paper, and placing a strong light source, such as a 100 W incandescent bulb inside the box.

LABORATORY-EXPERIMENT TEST INSTRUMENT 51

HEIGHT OF A DISTANT OBJECT USING A PINHOLE CAMERA

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a civil engineer. Sometimes engineers use an indirect method to determine the height of an object such as a building. Your problem is to design and implement a method to indirectly determine the height of an object placed at a distance of _____ cm from the pinhole of the camera.

Materials

distant object of unknown height
metre stick
metric ruler (calibrated in mm)
pinhole camera
tape measure

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the image height, image distance, object height, and object distance. The diagram need not be to scale.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

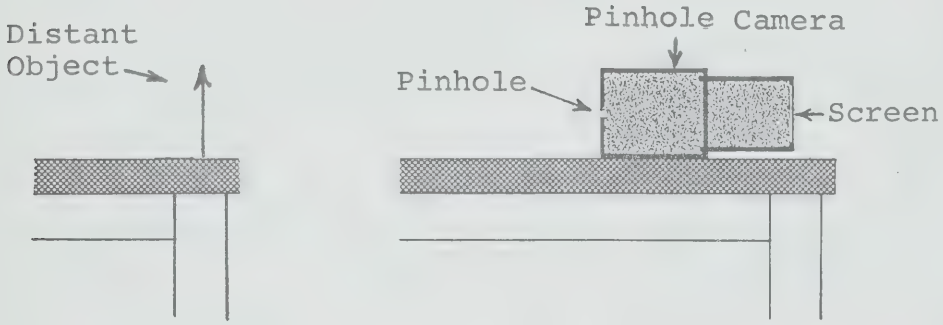
PROCEDURE SHEET 51

HEIGHT OF A DISTANT OBJECT USING A PINHOLE CAMERA

Note: Return this sheet to your examiner at the end of the test.

Method

a. Point the pinhole toward the distant object as shown in the diagram.



b. Adjust the position of the screen to obtain the largest possible complete image on the screen.

c. Measure the height of the image.

d. Measure the distance of the image from the pinhole.

e. Record the distance of the object from the pinhole.

f. Use these variables to calculate the height of the object. Show all calculations.

g. Draw a diagram and label the image height, image distance, object height, and object distance. The diagram need not be to scale.

h. When you have finished, submit this procedure sheet, the diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 52

RADIUS OF CURVATURE OF A CONCAVE MIRROR: USING A FIXED DISTANT OBJECT

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (15 min)

273
271

2. Minimum number of students: 1

3. Prerequisite knowledge:

A7
C4
D1

a.	centre of curvature C	e.	focus F
b.	characteristics of the image of a distant object and an object at C	f.	parallel ray
		g.	radius of curvature r
		h.	real image
c.	centre ray	i.	$r = 2\ f$
d.	focal length f	j.	terminology for concave mirrors

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4. Preparation:

   a. Provide a fixed distant light source or use a distant object such as a doorway or a window at the end of a hallway.

   b. Permit only one set up at a given location.

   c. Determine acceptable values by experiment.

LABORATORY-EXPERIMENT TEST INSTRUMENT 52

RADIUS OF CURVATURE OF A CONCAVE MIRROR: USING A FIXED DISTANT OBJECT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working in an optics laboratory. Your supervisor has given you a concave mirror and asked you to determine its radius of curvature using the light from a fixed distant object.

Materials

concave mirror of unknown focal length
metre stick
mirror holder
optical bench
small, fixed light source or object
screen

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up. Also draw a ray diagram showing how you will use the light from the fixed distant object to determine the radius of curvature.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 52

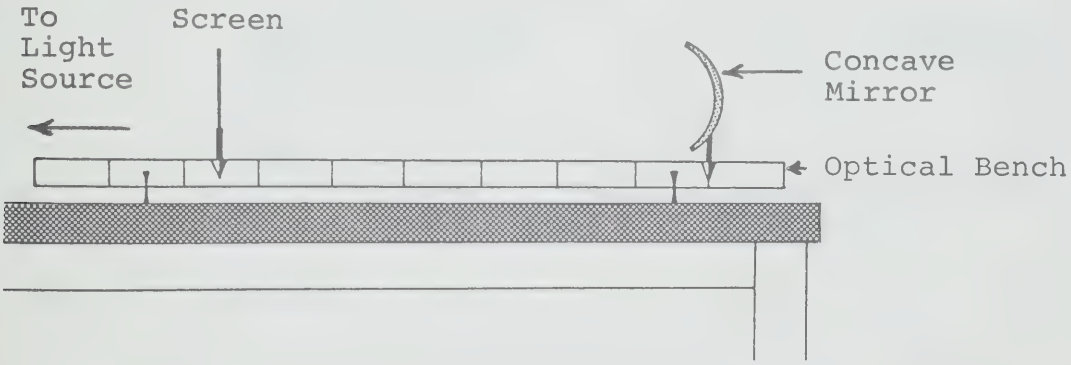
RADIUS OF CURVATURE OF A CONCAVE MIRROR: USING A FIXED DISTANT OBJECT

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the distant light source at the far end of the room.

b. Point the mirror at the light source as shown in the diagram.



c. Move the screen back and forth until the image of the light source is clearly focused on the screen.

d. Measure the distance between the mirror and the image.

e. Draw a ray diagram showing how the image is formed on the screen.

f. Determine the radius of curvature of the mirror.

g. When you have finished, submit this procedure sheet, the ray diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 53

RADIUS OF CURVATURE OF A CONCAVE MIRROR: USING A MOVABLE NEAR OBJECT

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (15 min)

273
271

2. Minimum number of students: 1

3. Prerequisite knowledge:

A7
C4
D1

- a. centre of curvature C
- b. characteristics of the image of a distant object and an object at C
- c. centre ray
- d. focal length f
- e. focus F
- f. parallel ray
- g. radius of curvature r
- h. real image
- i. $r = 2f$
- j. terminology for concave mirrors

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4. Preparation:

   a. Provide a small movable light source or object.

   b. Permit only one set up at a given location.

   c. Determine acceptable values by experiment.

LABORATORY-EXPERIMENT TEST INSTRUMENT 53

RADIUS OF CURVATURE OF A CONCAVE MIRROR: USING A MOVABLE NEAR OBJECT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working in an optics laboratory. Your supervisor has given you a concave mirror and asked you to determine its radius of curvature using the light from a movable near object.

Materials

concave mirror of unknown focal length
metre stick
mirror holder
optical bench
small movable light source or object
screen

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up. Also draw a ray diagram showing how you will use the light from the movable near object to determine the radius of curvature.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

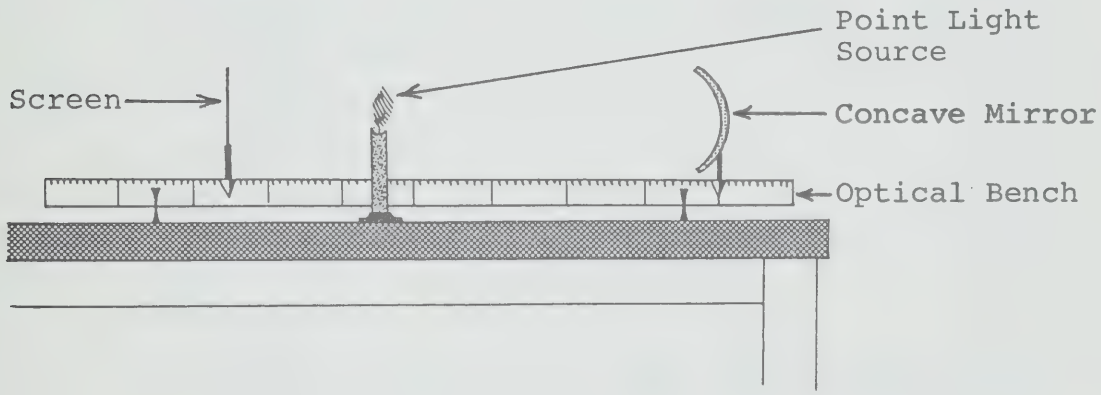
PROCEDURE SHEET 53

RADIUS OF CURVATURE OF A CONCAVE MIRROR: USING A MOVABLE NEAR OBJECT

Note: Return this sheet to your examiner at the end of the test.

Method B

a. Place the small movable light source near the mirror, as shown in the diagram.



b. Move the screen until it is directly beside the light source.

c. Angle the mirror to cast the reflected beam onto the screen.

d. Move the mirror back and forth until the image of the light source is clearly focused on the screen.

e. Measure the distance between the mirror and the image.

f. Use this distance to determine the radius of curvature of the mirror.

g. Draw a ray diagram showing how the image is formed on the screen.

h. When you have finished, submit this procedure sheet, the ray diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 54

FOCAL LENGTH OF A CONCAVE MIRROR: USING A FIXED DISTANT OBJECT

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

273

2. Minimum number of students: 1

A7
C4
D1

3. Prerequisite knowledge:

   a. characteristics of an image of a distant object

*

   b. focal length f

-

   c. focus F

**

   d. parallel ray

   e. real image

   f. terminology for concave mirrors

4. Preparation:

   a. Provide a fixed distant light source or use a distant object such as a doorway or a window at the end of a long hallway.

   b. Permit only one set up to a given location.

   c. Determine an acceptable value by experiment.

LABORATORY-EXPERIMENT TEST INSTRUMENT 54

FOCAL LENGTH OF A CONCAVE MIRROR: USING A FIXED DISTANT OBJECT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working in an optics laboratory. You have been told to determine the focal length of a concave mirror using a fixed distant object.

Materials

concave mirror of unknown focal length
fixed distant object
metre stick
mirror holder
optical bench
screen

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up. Also draw a ray diagram showing how to use the light from a distant object to determine the focal length.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 54

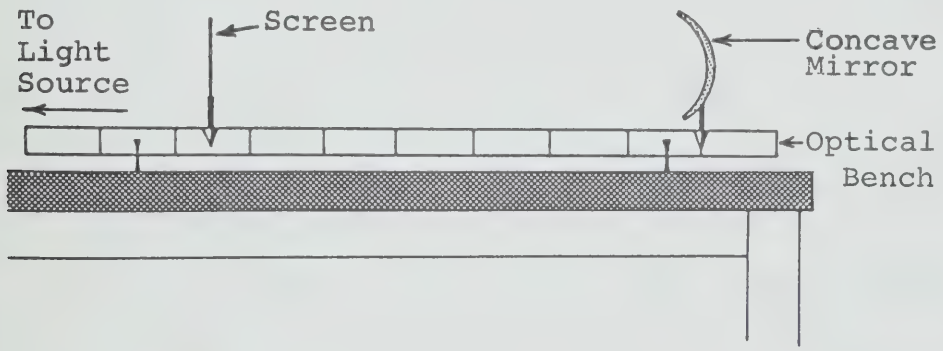
FOCAL LENGTH OF A CONCAVE MIRROR: USING A FIXED DISTANT OBJECT

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the light source at the far end of the room.

b. Point the mirror at the light source as shown in the diagram.



c. Move the screen back and forth until the image of the light source is clearly focused on the screen.

d. Measure the distance between the mirror and the image.

e. Determine the focal length of the mirror.

f. Draw a ray diagram showing how the image is formed on the screen.

g. When you have finished, submit this procedure sheet, the ray diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 55

FOCAL LENGTH OF A CONCAVE MIRROR: USING A MOVABLE NEAR OBJECT

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (20 min)

273

2. Minimum number of students: 1

A7
C4
D1

3. Prerequisite knowledge:

   a. characteristics of an image of a distant object

*

   b. focal length *f*

-

   c. focus *F*

**

   d. parallel ray

   e. real image

   f. terminology for concave mirrors

4. Preparation:

   a. Provide a small, movable light source or object.

   b. Permit only one set up to a given location.

   c. Determine an acceptable value by experiment.

LABORATORY-EXPERIMENT TEST INSTRUMENT 55

FOCAL LENGTH OF A CONCAVE MIRROR: USING A MOVABLE NEAR OBJECT

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working in an optics laboratory. You have been told to determine the focal length of a concave mirror using a movable near object.

Materials

concave mirror of unknown focal length
metre stick
mirror holder
movable near object
optical bench
screen

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up. Also draw a ray diagram showing how to use the light from a movable near object to determine the focal length.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

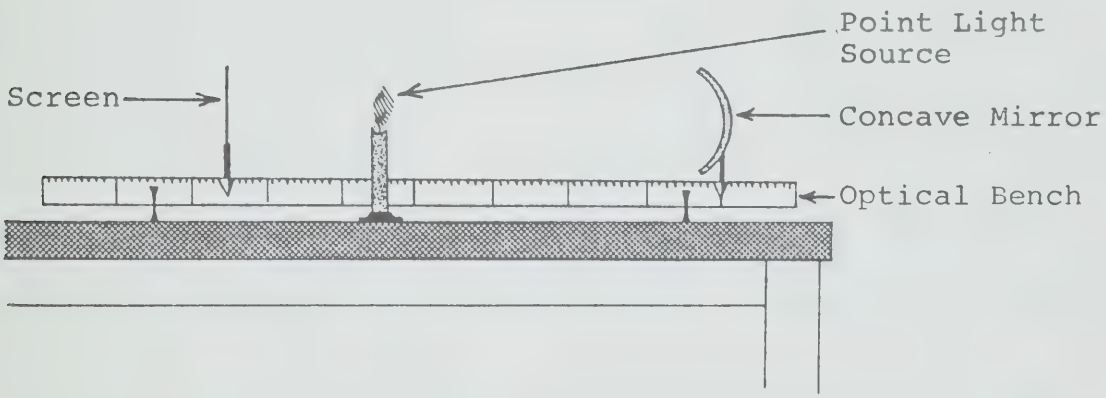
PROCEDURE SHEET 55

FOCAL LENGTH OF A CONCAVE MIRROR: USING A MOVABLE NEAR OBJECT

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the small movable light source near the mirror, as shown in the diagram.



b. Move the screen until it is directly beside the light source.

c. Angle the mirror to cast the reflected beam onto the screen.

d. Move the mirror back and forth until the image of the light source is clearly focused on the screen.

e. Measure the distance between the mirror and the image.

f. Use this distance to determine the focal length of the mirror.

g. Draw a ray diagram showing how the image is formed on the screen.

h. When you have finished, submit this procedure sheet, the ray diagram, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 56

VIRTUAL IMAGE USING A CONCAVE MIRROR

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (25 min)

S 275

2. Minimum number of students: 2

A7
B3

3. Prerequisite knowledge:

   a. correcting for parallax
   b. finder object
   c. focal length f
   d. parallax
   e. principal focus F
   f. terminology for a concave mirror
   g. virtual image

**
-
**

4. Preparation:

   a. This exercise is designed to test the students' skill at using the method of eliminating parallax to locate the virtual image of an object in front of a concave mirror.

   b. Have a student place the object at a specified position between the principal focus and the vertex of the mirror. Record the distance from the vertex in the space provided at the end of the problem statement in the Laboratory-Experiment Test Instrument.

   c. Different stations can be set up around the room by specifying different distances from the vertex for the object and by using mirrors of different focal lengths.

   d. The finder object must be tall enough to stand slightly above the mirror. A long nail with a large head to serve as a base, or a knitting needle inserted in a styrofoam base, work well.

LABORATORY-EXPERIMENT TEST INSTRUMENT 56

VIRTUAL IMAGE USING A CONCAVE MIRROR

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a magician's helper. The magician has instructed you to place an object _____ cm from the vertex of a concave mirror. You are to use the method of no parallax to determine the distance from the image to the vertex of the mirror.

Materials

concave mirror
finder object
metre stick
mirror holder
optical bench
real object

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the experiment set up. Include a ray diagram showing how the virtual image is formed.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

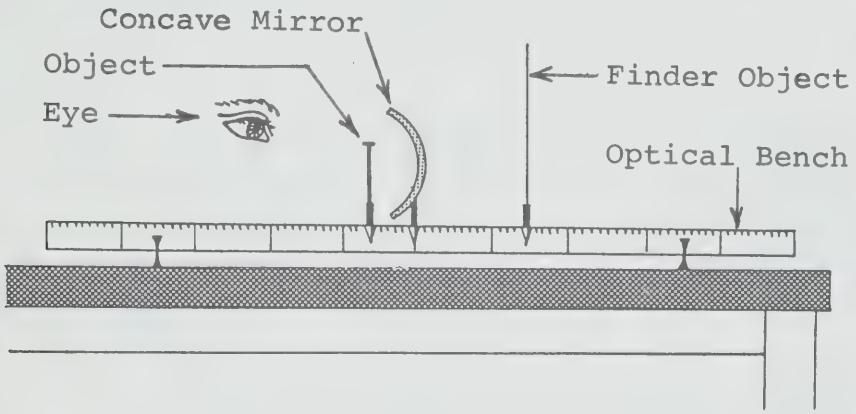
PROCEDURE SHEET 56

VIRTUAL IMAGE USING A CONCAVE MIRROR

Note: Return this sheet to your examiner at the end of the test.

Method

a. Set up the mirror on the optical bench as shown in the diagram.



b. Place the object in front of the mirror at the distance from the mirror specified by the examiner.

c. Record the distance of the object from the vertex and maintain this distance.

d. Place the finder object behind the mirror where the image appears to be.

e. Position your eyes so that you can look into the mirror at the image and over top at the finder object without moving your head.

f. Adjust the finder object back and forth. For each position of the finder object, move your head from side to side until there is no parallax between the image and the finder object.

g. Measure and record the distance of the finder object from the vertex. This is the distance of the image from the vertex.

h. Measure and record the distance of the real object from the vertex.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 57

VIRTUAL IMAGE USING A CONVEX MIRROR

Notes to the Teacher

S17A
II.3.a

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (20 min)

S 275

2. Minimum number of students: 2

A7
B3

3. Prerequisite knowledge:

**
-
**

a. correcting for parallax
b. finder object
c. focal length *f*
d. parallax
e. principal focus *F*
f. terminology for a convex mirror
g. virtual image

4. Preparation:

a. This exercise is designed to test the students' skill at using the method of eliminating parallax to locate the virtual image of an object in front of a convex mirror.

b. Have a student place the object at a specified position between the principal focus and the vertex of the mirror, but preferably within 20 cm of the mirror. Record the distance from the vertex in the space provided at the end of the problem statement in the Laboratory-Experiment Test Instrument.

c. Different stations can be set up around the room by specifying different distances from the vertex for the object and by using mirrors of different focal lengths.

d. The finder object must be tall enough to stand slightly above the mirror. A long nail with a large head to serve as a base, or a knitting needle inserted in a styrofoam base, work well.

LABORATORY-EXPERIMENT TEST INSTRUMENT 57

VIRTUAL IMAGE USING A CONVEX MIRROR

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a magician's helper. The magician has instructed you to place an object _____ cm from the vertex of a convex mirror. You are to use the method of no parallax to determine the distance from the image to the vertex of the mirror.

Materials

convex mirror
finder object
metric ruler
mirror holder
optical bench
real object

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the experiment set up. Include a ray diagram showing how the virtual image is formed.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Accuracy" identify and discuss possible sources of error.**

d) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

e) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

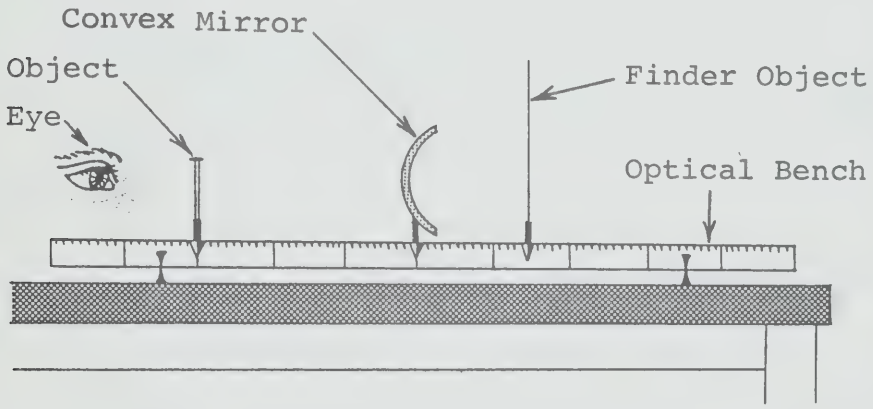
PROCEDURE SHEET 57

VIRTUAL IMAGE USING A CONVEX MIRROR

Note: Return this sheet to your examiner at the end of the test.

Method

a. Set up the mirror on the optical bench as shown in the diagram.



b. Place the object in front of the mirror at the distance from the mirror specified by the examiner.

c. Record the distance of the object from the vertex and maintain this distance.

d. Look into the mirror to see the virtual image.

e. Place the finder object behind the mirror where the image appears to be.

f. Position your eyes so that you can look into the mirror at the image and over top at the finder object without moving your head as shown in the diagram.

g. Adjust the finder object back and forth. For each position of the finder object move your head from side to side until there is no parallax between the image and the finder object.

h. Measure and record the distance of the finder object from the vertex. This is the distance of the image from the vertex.

i. Measure and record the distance of the real object from the vertex.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 58

FOCAL LENGTH OF A CONVERGING LENS

Notes to the Teacher

S17A
II.3.b

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (15 min)

295

2. Minimum number of students: 1

A7
C4
D1

3. Prerequisite knowledge:

   a. characteristics of an image of a distant object

*

   b. focal length f

-

   c. parallel ray

**

   d. principal focus F

   e. real image

   f. terminology for a converging lens

4. Preparation:

   a. Provide a small movable light source, or use a distant object such as a doorway or a window at the end of a long hallway.

   b. Permit only one set up in a given location.

   c. Determine an acceptable value by experiment.

LABORATORY-EXPERIMENT TEST INSTRUMENT 58

FOCAL LENGTH OF A CONVERGING LENS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working in an optics laboratory. You have been told to determine the focal length of a converging lens.

Materials

converging (convex) lens of unknown focal length
lens holder
metre stick
optical bench
small movable light source
screen

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the experiment set up. Include a ray diagram showing how the image is formed.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 58

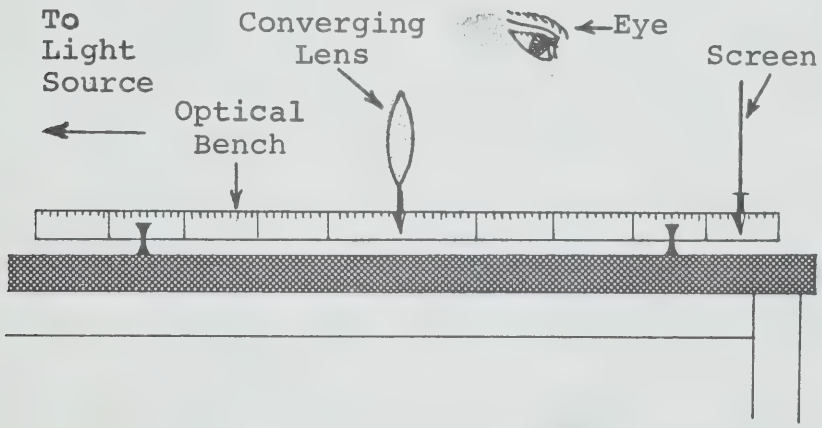
FOCAL LENGTH OF A CONVERGING LENS

Note: Return this sheet to your examiner at the end of the test.

Method

a. Place the light source at the far end of the room.

b. Place the lens between the light source and the screen as shown in the diagram.



c. Move the screen back and forth until the image of the light source is clearly focused on the screen.

d. Measure the distance between the lens and the image.

e. Determine the focal length of the lens.

f. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 59

VIRTUAL IMAGE USING A DIVERGING LENS

Notes to the Teacher

S17A
II.3.b

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (20 min)

S 297

2. Minimum number of students: 2

A7
B3

3. Prerequisite knowledge:

**
-
**

a. correcting for parallax
b. finder object
c. focal length f
d. optical centre
e. parallax
f. terminology for a diverging lens
g. virtual image
h. virtual principal focus F^1

4. Preparation:

a. This exercise is designed to test the students' skill at using the method of eliminating parallax to locate the virtual image of an object in front of a diverging lens.

b. Have a student place the object at a specified position between the principal focus and the optical centre of the lens. Record the distance from the optical centre of the diverging lens in the space provided at the end of the problem statement in the Laboratory-Experiment Test Instrument.

c. Different stations can be set up around the room by specifying different distances for the object from the optical centre and by using lenses of different focal lengths.

d. The finder object must be tall enough to stand slightly above the lens. A long nail with a large head to serve as a base, or a knitting needle inserted in a styrofoam base, work well.

LABORATORY-EXPERIMENT TEST INSTRUMENT 59

VIRTUAL IMAGE USING A DIVERGING LENS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are helping an oculist. The oculist has instructed you to place an object _____ cm from the optical centre of the diverging lens. Your problem is to design and implement a method to determine the distance of the virtual image from the optical centre of the diverging lens using the method of no parallax.

Materials

diverging (concave) lens
finder object
lens holder
metric ruler
optical bench
real object

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the experiment set up. Include a ray diagram showing how the virtual image is formed.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

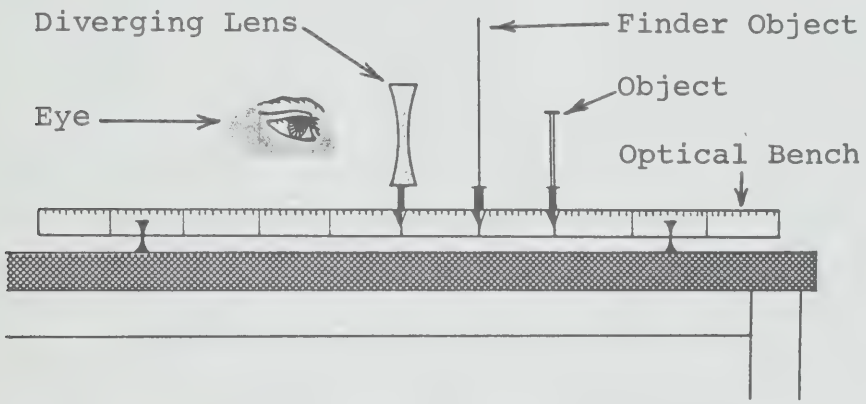
PROCEDURE SHEET 59

VIRTUAL IMAGE USING A DIVERGING LENS

Note: Return this sheet to your examiner at the end of the test.

Method

a. Set up the lens on the optical bench as shown in the diagram.



b. Place the object at the distance from the lens specified by the examiner.

c. Record the distance of the object from the optical centre of the lens and maintain this distance.

d. Look through the lens toward the object to see the virtual image.

e. Place the finder object where the image appears to be.

f. Position your eyes so that you can look into the lens, over top at the image, and at the finder object without moving your head, as shown in the diagram.

g. Adjust the finder object back and forth. For each position of the finder object, move your head from side to side until there is no parallax between the image and the finder object.

h. Measure and record the distance of the finder object from the optical centre of the lens. This is the distance of the image from the optical centre of the lens.

VIRTUAL IMAGE USING A DIVERGING LENS

Method continued

i. Measure and record the distance of the real object from the optical centre of the lens.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 60

VIRTUAL IMAGE USING A CONVERGING LENS

Notes to the Teacher

S17A
II.3.b

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (20 min)

S 297

2. Minimum number of students: 2

A7
B3

3. Prerequisite knowledge:

**
-
**

a. correcting for parallax
b. finder object
c. focal length *f*
d. optical centre
e. parallax
f. principal focus *F*
g. terminology for a converging lens
h. virtual image

4. Preparation:

a. This exercise is designed to test the students' skill at using the method of eliminating parallax to locate the virtual image of an object in front of a converging lens.

b. Have a student place the object at a specified position between the principal focus and the optical centre of the lens. Record the distance from the optical centre of the converging lens in the space provided in the problem statement in the Laboratory-Experiment Test Instrument.

c. Different stations can be set up around the room by specifying different distances for the object from the optical centre and by using lenses of different focal lengths.

d. The finder object must be tall enough to stand slightly above the lens. A long nail with a large head to serve as a base, or a knitting needle inserted in a styrofoam base, work well.

LABORATORY-EXPERIMENT TEST INSTRUMENT 60

VIRTUAL IMAGE USING A CONVERGING LENS

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are helping an oculist. The oculist has instructed you to place an object _____ cm from the optical centre of the converging lens. Your problem is to design and implement a method to determine the distance from the virtual image to the centre of the lens using the method of no parallax.

Materials

converging (convex) lens
finder object
lens holder
metric ruler
optical bench
real object

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the experiment set up. Include a ray diagram showing how the virtual image is formed.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Accuracy" identify and discuss possible sources of error.

d) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

e) When you have finished "Part B - Experiment Report" submit it to your examiner.

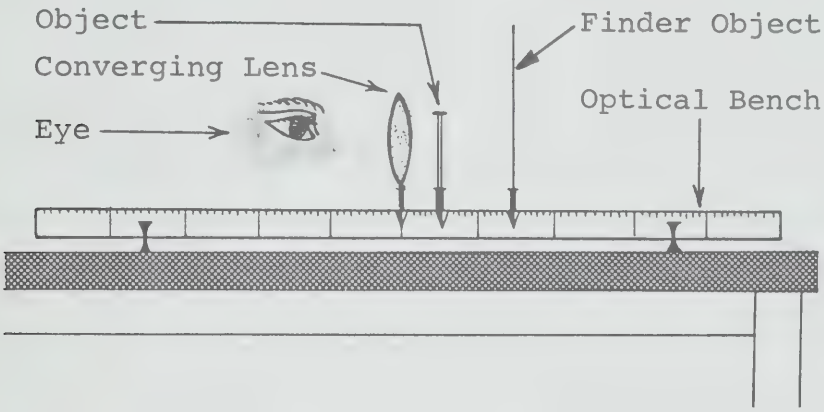
PROCEDURE SHEET 60

VIRTUAL IMAGE USING A CONVERGING LENS

Note: Return this sheet to your examiner at the end of the test.

Method

a. Set up the lens on the optical bench as shown in the diagram.



b. Place the object at the distance from the lens specified by the examiner.

c. Record the distance of the object from the optical centre of the lens and maintain this distance.

d. Look through the lens toward the object to see the virtual image.

e. Place the finder object where the image appears to be.

f. Position your eyes so that you can look into the lens at the image and over top at the finder object without moving your head, as shown in the diagram.

g. Adjust the finder object back and forth. For each position of the finder object, move your head from side to side until there is no parallax between the image and the finder object.

h. Measure and record the distance of the finder object from the optical centre of the lens. This is the distance of the image from the optical centre of the lens.

Method continued

i. Measure and record the distance of the real object from the optical centre of the lens.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 61

DENSITY OF A REGULAR SOLID

Notes to the Teacher

345

1. Suggested schedule: Part A - Experiment Design (10 min)
   Part B - Experiment Report (20 min)

A7
B3
C4
D3

2. Minimum number of students: 1

3. Prerequisite knowledge:

-
-
*

a. $D = m/V$
b. density D
c. density of a regular solid
d. mass m
e. SI units of density
f. volume V

4. Preparation:

   a. Use a solid shape familiar to the student, such as a cube, a cylinder, or a sphere. Paint the solid to prevent visual identification of the material.

   b. Provide the student with a table of densities in kg/m^3.

   c. Identify the materials in the table as A, B, C, etc. rather than by name to prevent identification by other properties.

   d. Ensure a realistic range of densities to permit identification.

   e. Different stations can be set up around the room by using different materials.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 61

DENSITY OF A REGULAR SOLID

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working as a technologist and you have been given a sample of material to identify. Your problem is to design and implement a method to determine the density of the regular solid sample, and to identify the material making up the solid sample from its density.

Materials

balance
regular solid
ruler
set of standard masses
table of densities

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

d) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

PROCEDURE SHEET 61

DENSITY OF A REGULAR SOLID

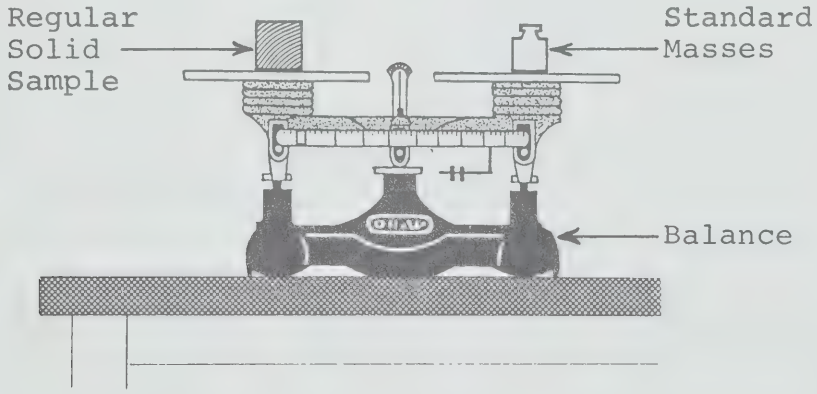
Note: Return this sheet to your examiner at the end of the test.

Method

a. Measure and record the linear dimensions of the regular solid.

b. Calculate the volume of the solid using the appropriate formula: cylinder ($V = \pi r^2 h$), rectangular prism ($V = lwh$), sphere ($V = 4/3\ \pi r^3$).

c. Measure and record the mass of the object using a balance as shown in the diagram.



d. Determine the density of the solid. Show all calculations.

e. Convert the density value to the same units as the table provided. Show any conversion.

f. Consult the table of densities to identify a possible material making up the regular solid.

g. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 62

DENSITY OF AN IRREGULAR SOLID

Notes to the Teacher

345

A7
B3
C4
D3

1. Suggested schedule: Part A - Experiment Design (10 min)
   Part B - Experiment Report (20 min)

2. Minimum number of students: 1

3. Prerequisite knowledge:

-
-
*

   a. $D = m/V$
   b. density D
   c. density of an irregular solid
   d. finding volume by displacement of a liquid
   e. mass m
   f. SI units of density
   g. volume V

4. Preparation:

   a. Paint the irregular solid to prevent visual identification of the material.
   b. Provide the student with a table of densities in kg/m^3.
   c. Identify the materials by letter rather than by name to prevent identification by other properties.
   d. Provide a graduated cylinder which is large enough to immerse the solid, but calibrated as finely as possible to improve the accuracy.
   e. Different stations can be set up around the room by using different materials.

5. CAUTION:

   WARN THE STUDENTS ABOUT THE DANGER OF DROPPING THE IRREGULAR SOLID INTO A GLASS GRADUATED CYLINDER.

LABORATORY-EXPERIMENT TEST INSTRUMENT 62

DENSITY OF AN IRREGULAR SOLID

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are working as a technologist and you have been given a sample of material to identify. Your problem is to design and implement a method to determine the density of an irregular solid and to identify the material making up the solid sample from its density.

Materials

balance	set of standard masses
dissecting needle	table of densities
graduated cylinder	thread
irregular solid	water

CAUTION: DO NOT DROP THE IRREGULAR SOLID INTO THE GRADUATED CYLINDER.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

d) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

PROCEDURE SHEET 62

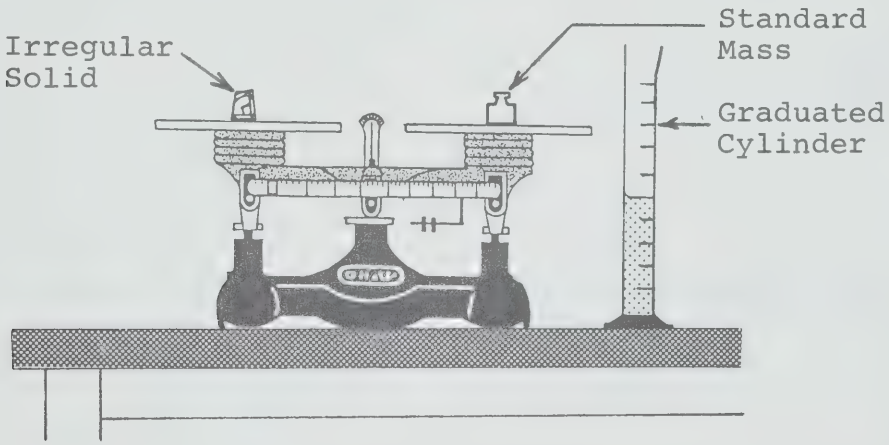
DENSITY OF AN IRREGULAR SOLID

Note: Return this sheet to your examiner at the end of the test.

Method

a. Measure and record the mass of the object.

b. Partially fill the graduated cylinder with water as shown in the diagram.



c. Read and record the volume of the water.

d. Tie a thread to the object and carefully lower it into the water until it is completely covered. If necessary, use the dissecting needle to submerge the object.

e. Read and record the volume of the water and the object.

f. Determine the volume of the object. Show all calculations.

g. Determine the density of the object. Show all calculations.

h. Convert the density value to the same units as the table provided.

i. Consult the table of densities to identify a possible material making up the irregular solid.

j. When you have finished, submit this procedure sheet, and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 63

DENSITY OF A LIQUID USING A GRADUATED CYLINDER

Notes to the Teacher

345

1. Suggested schedule: Part A - Experiment Design (10 min)
   Part B - Experiment Report (20 min)

A7
B3
C4
D3

2. Minimum number of students: 1

3. Prerequisite knowledge:

-
-
*

   a. $D = m/V$
   b. density D
   c. mass m
   d. SI unit of density
   e. volume V

4. Preparation:

   a. Do not use mercury, carbon tetrachloride, methyl alcohol, or any other liquid which might be harmful to the health.
   b. Some appropriate liquids are water, ethylene glycol, and brine.
   c. Use a liquid that is easy to clean from glassware.
   d. Provide the students with a table of densities in kg/m^3.
   e. Different stations can be set up around the room by using different liquids.

LABORATORY-EXPERIMENT TEST INSTRUMENT 63

DENSITY OF A LIQUID USING A GRADUATED CYLINDER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist working in a forensic science laboratory. Your problem is to design and implement a method to determine the density of a liquid and to identify the liquid from its density.

Materials

balance
beaker
graduated cylinder
liquid
paper towel
ruler graduated in mm
set of standard masses
table of densities

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

d) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

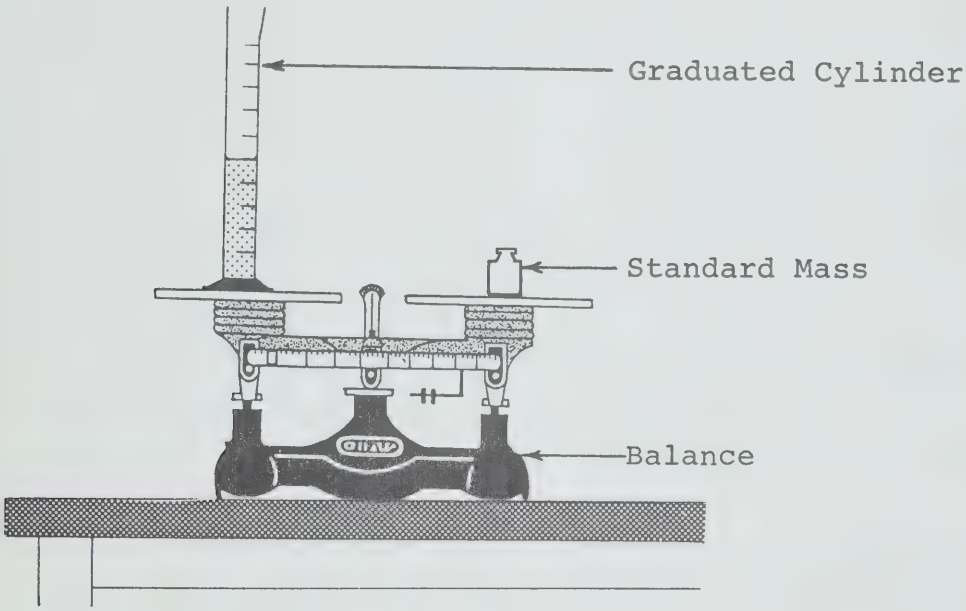
PROCEDURE SHEET 63

DENSITY OF A LIQUID USING A GRADUATED CYLINDER

Note: Return this sheet to your examiner at the end of the test.

Method

a. Use the equipment shown in the diagram.



b. Measure and record the mass of a clean, dry, graduated cylinder.

c. Fill the graduated cylinder nearly full with a liquid. Read and record the volume of the liquid.

d. Measure and record the mass of the liquid plus graduated cylinder.

e. Determine the mass of the liquid.

f. Determine the density of the liquid. Show all calculations.

g. Convert the density value to the same units as the table provided.

h. Consult the table of densities to identify the liquid.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 64

DENSITY OF A LIQUID USING A PYKNOMETER

Notes to the Teacher

345

1. Suggested schedule: Part A - Experiment Design (10 min)
   Part B - Experiment Report (20 min)

A7
B3
C4
D3

2. Minimum number of students: 1

3. Prerequisite knowledge:

- a. $D = m/V$
- b. density D
- c. mass m
- d. SI unit of density
- e. using a pyknometer
- f. volume V

4. Preparation:

   a. Do not use mercury, carbon tetrachloride, methyl alcohol, or any other liquid which might be harmful to the health.

   b. Some appropriate liquids are water, ethylene glycol, and brine.

   c. Use liquids that are easy to clean from glassware.

   d. Provide the students with a table of densities in kg/m^3.

   e. Different stations can be set up around the room by using different liquids.

   f. A pyknometer (specific gravity bottle) is a glass vessel which is graduated to hold a specific volume of liquid at a specific temperature.

LABORATORY-EXPERIMENT TEST INSTRUMENT 64

DENSITY OF A LIQUID USING A PYKNOMETER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist working in a forensic science laboratory. Your problem is to design and implement a method to determine the density of a liquid and to identify the liquid from its density.

Materials

balance	paper towel
beaker	pyknometer (specific gravity bottle)
liquid	table of densities

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

d) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

PROCEDURE SHEET 64

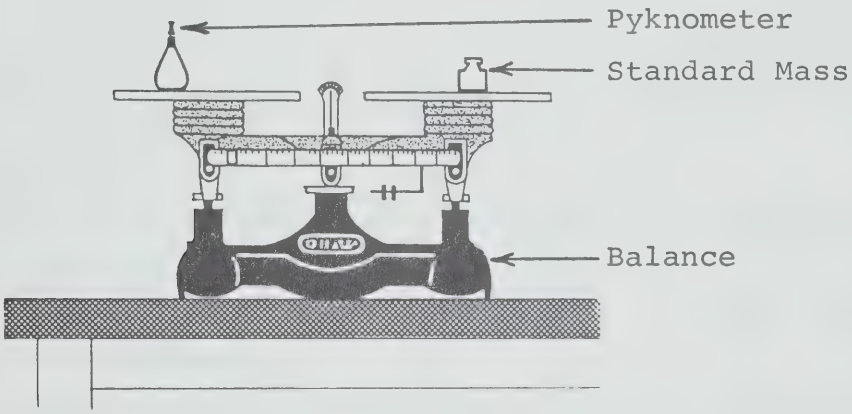
DENSITY OF A LIQUID USING A PYKNOMETER

Note: Return this sheet to your examiner at the end of the test.

Method

a. Carefully clean and dry the pyknometer.

b. Measure the mass of the empty pyknometer as shown in the diagram.



c. Fill the pyknometer completely with the liquid. Insert the stopper and wipe off any excess liquid from the outside.

d. Measure the mass of the pyknometer and liquid.

e. Determine the mass of the liquid in the pyknometer. Show all calculations.

f. Read the volume of the liquid in the pyknometer.

g. Determine the density of the liquid.

h. Convert the density value to the same unit as the table provided. Show any conversion.

i. Consult the table of densities to identify the liquid.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 65

RELATIVE DENSITY OF A LIQUID USING A PYKNOMETER

Notes to the Teacher

345

1. Suggested schedule: Part A - Experiment Design (10 min)
   Part B - Experiment Report (20 min)

A7
B3
C4
D3

2. Minimum number of students: 1

3. Prerequisite knowledge:

-
-
*

   a. $D = m/V$
   b. density D
   c. mass m
   d. SI unit of density
   e. using a pyknometer
   f. volume V

4. Preparation:

   a. Do not use mercury, carbon tetrachloride, methyl alcohol, or any other liquid which might be harmful to the health.
   b. Some appropriate liquids are water, ethylene glycol, and brine.
   c. Use liquids that are easy to clean from glassware.
   d. Provide the students with a table of relative densities.
   e. Different stations can be set up around the room by using different liquids.
   f. A pyknometer (specific gravity bottle) is a glass vessel which is graduated to hold a specific volume of liquid at a specific temperature.

LABORATORY-EXPERIMENT TEST INSTRUMENT 65

RELATIVE DENSITY OF A LIQUID USING A PYKNOMETER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a technologist working in a forensic science laboratory. Your problem is to design and implement a method to determine the relative density of the liquid and to identify the liquid from its relative density.

Materials

balance	paper towel
beaker	pyknometer (specific gravity bottle)
liquid	table of relative densities

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

d) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

PROCEDURE SHEET 65

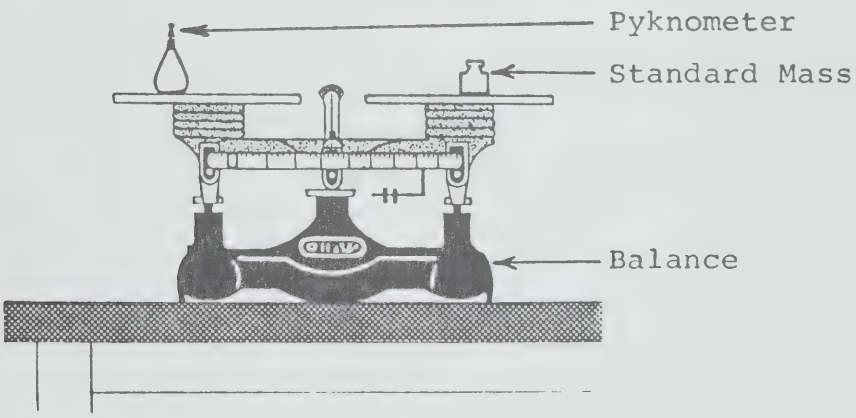
RELATIVE DENSITY OF A LIQUID USING A PYKNOMETER

Note: Return this sheet to your examiner at the end of the test.

Method

a. Carefully clean and dry the pyknometer.

b. Measure the mass of the empty pyknometer as shown in the diagram.



c. Fill the pyknometer completely with the liquid. Insert the stopper and wipe off any excess liquid from the outside.

d. Measure the mass of the pyknometer and liquid.

e. Determine the mass of the liquid in the pyknometer. Show all calculations.

f. Repeat steps c, d and e for water. Show all calculations.

g. Determine the relative density of the liquid.

h. Consult the table of relative densities to identify the liquid.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 66

SPECIFIC HEAT CAPACITY OF A METAL

Notes to the Teacher

379

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (35 min)

A7
B3
C4
D3

2. Minimum number of students: 2

3. Prerequisite knowledge:

-
-
**

a. heat energy Q
b. mass m
c. method of mixtures
d. principle of heat exchange
e. $Q = m \cdot \Delta T \cdot c$
f. specific heat capacity c
g. temperature T

4. Preparation:

   a. To obtain better results, use a metal with a high specific heat capacity such as aluminum.
   b. Paint the metals one colour to mask other properties.
   c. Identify the metals by letter rather than by name.
   d. Provide a table of specific heat capacities.
   e. Expect an error of between 5 and 20% depending on the mass and the specific heat capacity of the sample.
   f. Provide the specific heat capacity of water (4200 J/(kg·°C).

5. CAUTION:

   WARN THE STUDENTS ABOUT THE DANGERS OF HOT MATERIALS.

LABORATORY-EXPERIMENT TEST INSTRUMENT 66

SPECIFIC HEAT CAPACITY OF A METAL

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a metallurgist. Your task is to design and implement a method to determine the specific heat capacity of a metal sample.

Materials

adjustable clamp	100 mL graduated cylinder
balance	ring clamp
Bunsen burner	retort stand
Celsius thermometer	table of specific heat capacities
styrofoam cup	thread
metal sample	200 mL beaker
	wire gauze

CAUTION: HOT LIQUIDS AND HOT OBJECTS CAN BE DANGEROUS. BE CAREFUL!

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) **Under the heading "Problem" write in your own words a clear statement of the problem under investigation.**

b) **Examine the materials supplied by your examiner.**

c) **Under the heading "Diagram" draw a circuit diagram showing the proposed experiment set up.**

d) **Under the heading "Method" list in order the steps of the method you will use to solve the problem.**

e) **When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.**

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) **Perform the experiment by following the steps outlined in the procedure.**

b) **Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.**

c) **Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.**

d) **Under the heading "Accuracy" identify and discuss possible sources of error.**

e) **Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.**

f) **When you have finished "Part B - Experiment Report" submit it to your examiner.**

PROCEDURE SHEET 66

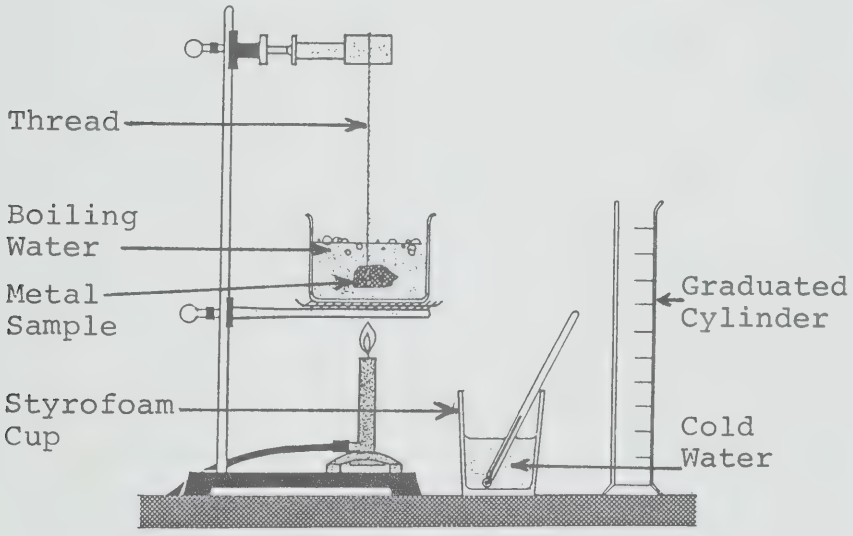
SPECIFIC HEAT CAPACITY OF A METAL

Note: Return this sheet to your examiner at the end of the test.

Method

a. Measure the mass of the metal.

b. Suspend the metal in the beaker above the bottom as shown in the diagram.



c. Cover the metal with water and boil the water for about five minutes.

d. Record the temperature of the boiling water. Assume that this is the initial temperature of the metal.

e. Add 100 g of cold water to a cup. Record the temperature of the cold water. This is the initial temperature of the cold water.

f. Quickly transfer the hot metal sample to the cold water. Make sure the cold water covers the metal.

g. Stir the mixture and record the highest temperature reached. This is the final temperature of both the cold water and the metal.

SPECIFIC HEAT CAPACITY OF A METAL

Method continued

h. Calculate the specific heat capacity of the metal. Assume that the specific heat capacity of water is 4200 J/(kg·°C).

i. Consult the table of specific heat capacities to identify the metal.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 67

SPECIFIC HEAT CAPACITY OF A LIQUID

Notes to the Teacher

379

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (35 min)

A7
B3
C4
D3

2. Minimum number of students: 2

3. Prerequisite knowledge:

-
-
**

   a. connecting and using an immersion heater
   b. heat energy Q
   c. mass m
   d. $Q = m \cdot \Delta T \cdot c$
   e. specific heat capacity c
   f. temperature T

4. Preparation:

   a. Coloured water, ethylene glycol, and glycerine are excellent liquids to use.
   b. Identify the liquids by letter rather than by name.
   c. Several stations can be set up around the room. Use a different liquid at each station.
   d. Cool the liquids to below room temperature before the experiment.
   e. Provide the power of the immersion heater in watts.
   f. Use an immersion heater having a power of between 30 W and 40 W. A safe D.C. immersion heater can be made by connecting two 2 Ω 10 W power resistors in parallel. When connected to a 6 V D.C. source, the heater draws a current of about 1 A.

5. CAUTION:

   a. DO NOT USE FLAMMABLE LIQUIDS.
   b. DO NOT USE 110 V A.C. IMMERSION HEATERS SINCE THEY ARE NOT CSA APPROVED AND COULD BE A SAFETY HAZARD.

LABORATORY-EXPERIMENT TEST INSTRUMENT 67

SPECIFIC HEAT CAPACITY OF A LIQUID

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are an engineer working for a heating company which uses liquids to store heat energy. Your task is to design and implement a method to determine the specific heat capacity of a liquid and to use the value to identify the liquid.

Materials

balance
Celsius thermometer
graduated cylinder
immersion heater
styrofoam cup
stirring rod
table of specific heat capacities
timer
unknown liquid

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 67

SPECIFIC HEAT CAPACITY OF A LIQUID

Note: Return this sheet to your examiner at the end of the test.

Method

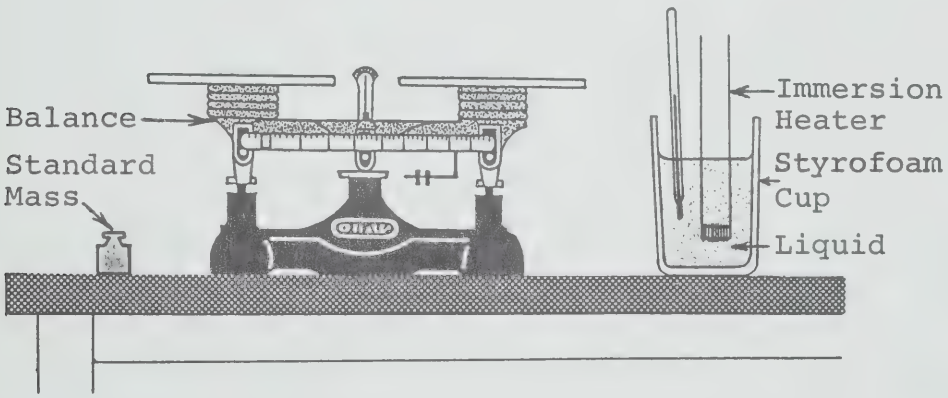
a. Record the power of the immersion heater in watts.

b. Measure the mass of a styrofoam cup.

c. Add liquid to the styrofoam cup until it is three-quarters full. Measure the mass of the liquid and styrofoam cup.

d. Determine the mass of the liquid in kilograms.

e. Place the immersion heater in the liquid so that the element is completely covered as shown in the diagram.



f. Record the starting temperature of the liquid.

g. Turn on the heater and record the starting time.

h. Stir continuously, and record the time it takes to produce a specific temperature change of approximately 40°C. Give the liquid a final stir after turning off the heater and record the highest temperature reached by the liquid.

i. Calculate the heat energy in joules supplied by the heater to the liquid. Show all calculations.

j. Calculate the specific heat capacity of the liquid. Show all calculations.

SPECIFIC HEAT CAPACITY OF A LIQUID

Method continued

k. Consult the table of specific heat capacities to identify the liquid.

l. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 68

ANALYSIS OF A SINGLE FIXED PULLEY

Notes to the Teacher

391 1. Suggested schedule: Part A - Experiment Design (20 min)
392 Part B - Experiment Report (25 min)
393

2. Minimum number of students: 1

A2
A8
B3
C4
D3

3. Prerequisite knowledge:

a. actual mechanical advantage *AMA*

** b. $AMA = \frac{F_l}{F_e}$
-
**

c. distance *d*

d. $E = \frac{W_l}{W_e} \times 100$

e. effort *e*

f. force *F*

g. ideal mechanical advantage *IMA*

h. $IMA = \frac{d_e}{d_l}$

i. load *l*

j. percent efficiency *E*

k. single fixed pulley

l. work *W*

4. Preparation:

a. Choose a pulley with a measurable amount of friction. One way to do this is to use a fixed rod as a pulley.

b. Several different stations can be set up by varying the load.

c. If possible, adjust the newton spring scale to read zero with the scale inverted.

LABORATORY-EXPERIMENT TEST INSTRUMENT 68

ANALYSIS OF A SINGLE FIXED PULLEY

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a sailor preparing for Canada's entry in the America's Cup challenge. Various kinds and makes of pulleys are being tested. Your problem is to determine the actual mechanical advantage, ideal mechanical advantage, and percent efficiency of a single fixed pulley.

Materials

adjustable clamp
C-clamp
light cord
load
metre stick
newton spring scale
retort stand
ring clamp
single pulley

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 68

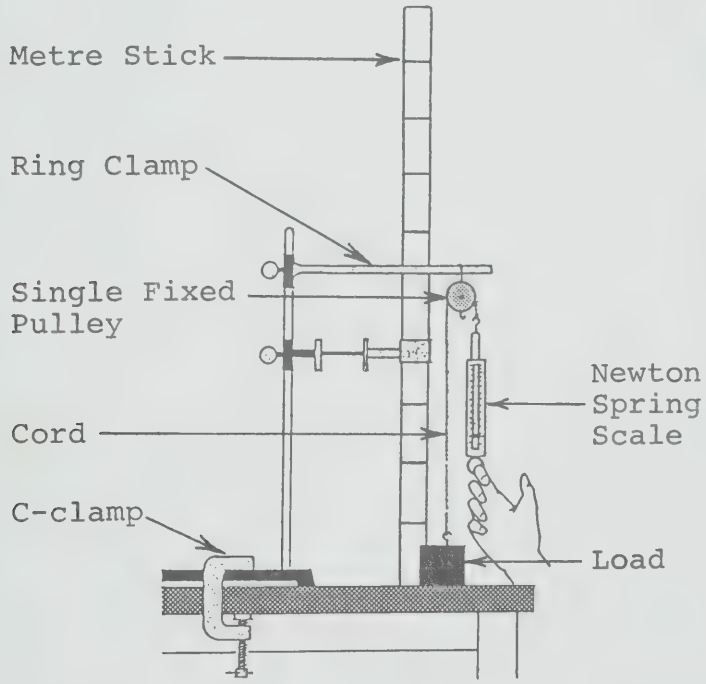
ANALYSIS OF A SINGLE FIXED PULLEY

Note: Return this sheet to your examiner at the end of the test.

Method

a. Use the newton spring scale to find the force to lift the load at constant speed without the pulley. This is the load force.

b. Set up the ring stand, clamp, support rod, fixed pulley, and load as shown in the diagram.



c. Pull down on the spring and measure and record the force to raise the load using the fixed pulley. This is the effort force.

d. Measure the distance moved by the effort force as the load moved 0.25 m upward.

e. Determine the actual mechanical advantage of this pulley. Show all calculations.

ANALYSIS OF A SINGLE FIXED PULLEY

Method continued

f. Determine the ideal mechanical advantage of the fixed pulley. Show all calculations.

g. Determine the percent efficiency of the pulley. Show all calculations.

h. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 69

ANALYSIS OF A MOVABLE PULLEY

Notes to the Teacher

391 1. Suggested schedule: Part A - Experiment Design (20 min)
392 Part B - Experiment Report (25 min)
393

2. Minimum number of students: 1

A2
A8
B3
C4
D3

3. Prerequisite knowledge:

** a. actual mechanical advantage *AMA*

\- b. $AMA = \frac{F_l}{F_e}$

** c. distance *d*

d. $E = \frac{W_l}{W_e} \times 100$

e. effort *e*

f. force *F*

g. ideal mechanical advantage *IMA*

h. $IMA = \frac{d_e}{d_l}$

i. load *l*

j. percent efficiency *E*

k. single movable pulley

l. work *W*

4. Preparation:

Several different stations can be set up by varying the load.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 69

ANALYSIS OF A MOVABLE PULLEY

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a sailor preparing for Canada's entry in the America's Cup challenge. Various kinds and makes of pulleys are being tested. Your problem is to determine the actual mechanical advantage, ideal mechanical advantage, and percent efficiency of a movable pulley.

Materials

adjustable clamp
C-clamp
load
light cord
metre stick
newton spring scale
retort stand
ring clamp
single pulley

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 69

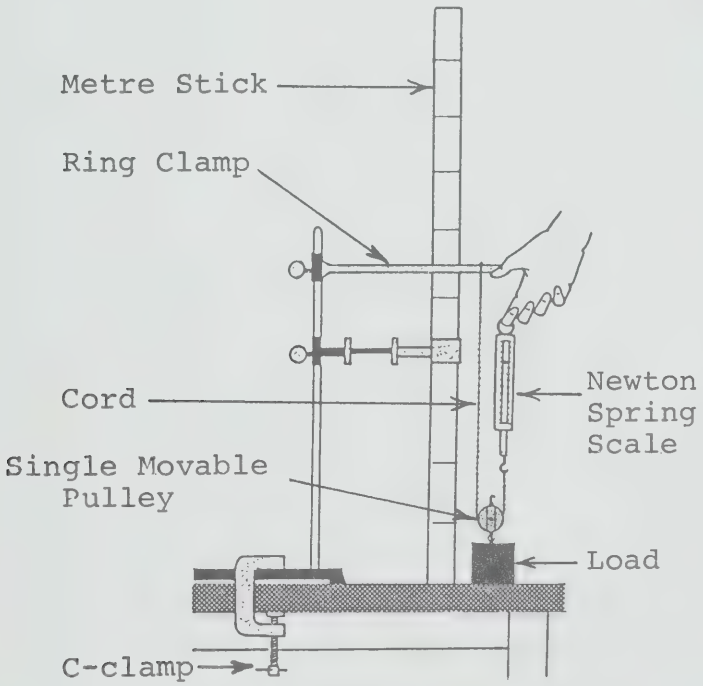
ANALYSIS OF A MOVABLE PULLEY

Note: Return this sheet to your examiner at the end of the test.

Method

a. Use the newton spring scale to find the force to lift the load at constant speed without the pulley. This is the load force.

b. Set up the ring stand, clamps, movable pulley, and load as shown in the diagram.



c. Pull up on the spring scale and measure and record the force to raise the load using the movable pulley. This is the effort force.

d. Measure the distance moved by the effort force as the load moved 0.25 m upward.

e. Determine the actual mechanical advantage of the pulley. Show all calculations.

ANALYSIS OF A MOVABLE PULLEY

Method continued

f. Determine the ideal mechanical advantage. Show all calculations.

g. Determine the percent efficiency of the pulley system. Show all calculations.

h. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 70

ANALYSIS OF A SIMPLE BLOCK AND TACKLE

Notes to the Teacher

391
392
393

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (25 min)

A2

2. Minimum number of students: 1

A8
B3
C4
D3

3. Prerequisite knowledge:

   a. actual mechanical advantage *AMA*

   b. $AMA = \frac{F_l}{F_e}$

   c. distance *d*

   d. $E = \frac{W_l}{W_e} \times 100$

   e. effort *e*

   f. force *F*

   g. ideal mechanical advantage *IMA*

   h. $IMA = \frac{d_e}{d_l}$

   i. load *l*

   j. percent efficiency *E*

   k. simple block and tackle

   l. work *W*

**
-
**

4. Preparation:

   a. Choose a fixed pulley with a measurable amount of friction for the simple block and tackle. One way to do this is to use a fixed horizontal rod as the fixed pulley (tackle).

   b. Several different stations can be set up by varying the load.

LABORATORY-EXPERIMENT

TEST INSTRUMENT 70

ANALYSIS OF A SIMPLE BLOCK AND TACKLE

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are a sailor preparing for Canada's entry in the America's Cup challenge. Various kinds of block and tackle are being tested. Your problem is to determine the actual mechanical advantage, ideal mechanical advantage, and percent efficiency of a simple block and tackle.

Materials

adjustable clamp
C-clamp
fixed pulley (tackle)
light cord
load
metre stick
movable pulley (block)
newton spring scale
retort stand
ring clamp

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 70

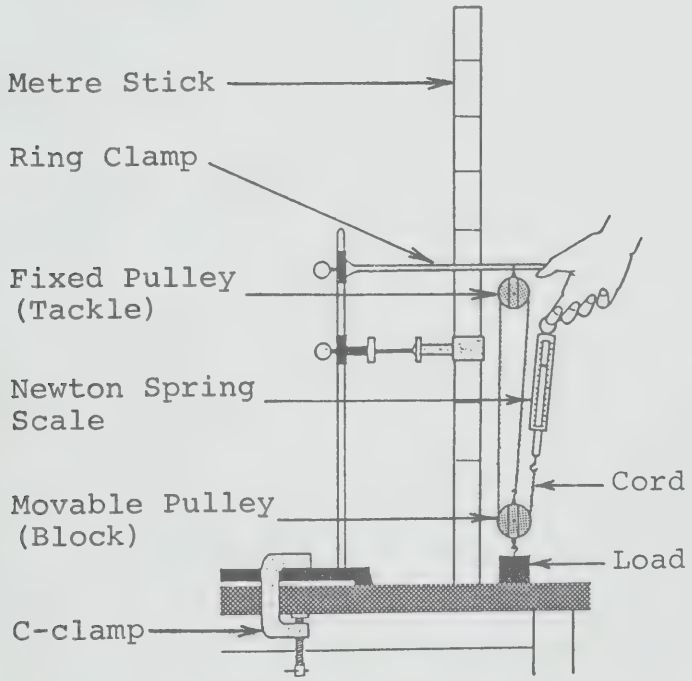
ANALYSIS OF A SIMPLE BLOCK AND TACKLE

Note: Return this sheet to your examiner at the end of the test.

Method

a. Use the newton spring scale to find the force to lift the load at constant speed without the block and tackle. This is the load force.

b. Set up the ring stand, clamp, fixed and movable pulleys, and load as shown in the diagram.



c. Pull up on the spring scale and measure and record the force to raise the load using the block and tackle. This is the effort force.

d. Measure the distance moved by the effort force as the load force moves 0.25 m upward.

e. Determine the actual mechanical advantage of the block and tackle. Show all calculations.

Method continued

f. Determine the ideal mechanical advantage of the block and tackle. Show all calculations.

g. Determine the percent efficiency of the block and tackle. Show all calculations.

h. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 71

ANALYSIS OF A FIRST CLASS LEVER

Notes to the Teacher

391 1. Suggested schedule: Part A - Experiment Design (20 min)
392 Part B - Experiment Report (25 min)
393

2. Minimum number of students: 2

A2
A8 3. Prerequisite knowledge:
B3
C4
D3

a. actual mechanical advantage *AMA*

b. $AMA = \frac{F_l}{F_e}$

c. distance *d*

d. $E = \frac{W_l}{W_e} \times 100$

e. effort *e*

f. first class lever

g. force *F*

h. fulcrum

i. ideal mechanical advantage *IMA*

j. $IMA = \frac{d_e}{d_l}$

k. load *l*

l. percent efficiency *E*

m. work *W*

** 4. Preparation:
-
**

a. Several different stations can be set up by varying the position of the fulcrum, the load, and the effort. Record the positions in the spaces provided in the problem statement in the Laboratory-Experiment Test Instrument.

b. Provide a newton spring scale having a range suitable for the load and effort.

c. To eliminate the effect of gravity, set up the apparatus in the horizontal plane and use another newton spring scale as the load.

LABORATORY-EXPERIMENT TEST INSTRUMENT 71

ANALYSIS OF A FIRST CLASS LEVER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are an engineer working for a company that manufactures heavy construction equipment. Your problem is to evaluate simple levers. Determine the ideal mechanical advantage, actual mechanical advantage, and percent efficiency of this first class lever for the following positions of the load, effort and fulcrum with reference to the zero end of the metre stick:

load _____cm; effort _____cm; fulcrum _____cm.

Materials

C-clamp
knife-edge holder
load
3 metre sticks
newton spring scale
paper clips or thread
retort stand, clamp, rod

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 71

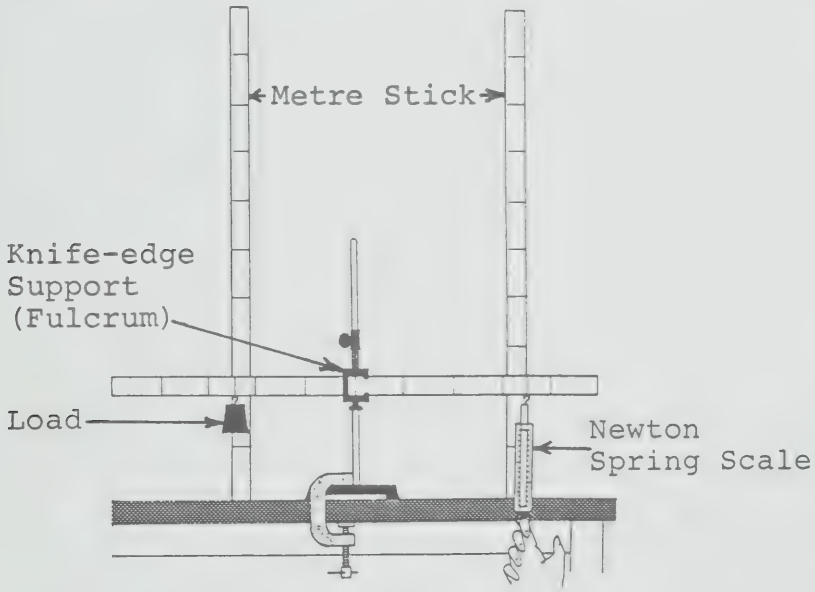
ANALYSIS OF A FIRST CLASS LEVER

Note: Return this sheet to your examiner at the end of the test.

Method

a. Use the newton spring scale to find the force to raise the load at constant speed without the lever. This is the load force.

b. Set up the first class lever, load and spring scale as shown in the diagram. Place the load, effort and fulcrum at the positions specified by your teacher.



c. Pull down on the spring scale and measure and record the force to raise the load using the first class lever. This is the effort force.

d. Measure the distance moved by the effort force as the load moves 0.10 m upward.

e. Determine the actual mechanical advantage of the lever. Show all calculations.

f. Determine the ideal mechanical advantage of the lever. Show all calculations.

ANALYSIS OF A FIRST CLASS LEVER

Method continued

g. Determine the percent efficiency of the lever. Show all calculations.

h. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 72

ANALYSIS OF A SECOND CLASS LEVER

Notes to the Teacher

391
392
393

1. Suggested schedule: Part A - Experiment Design (20 min)
   Part B - Experiment Report (25 min)

2. Minimum number of students: 2

A2
A8
B3
C4
D3

3. Prerequisite knowledge:

   a. actual mechanical advantage *AMA*

   b. $AMA = \frac{F_l}{F_e}$

   c. distance *d*

   d. $E = \frac{W_l}{W_e} \times 100$

   e. effort *e*

   f. force *F*

   g. fulcrum

   h. ideal mechanical advantage *IMA*

   i. $IMA = \frac{d_e}{d_l}$

   j. load *l*

   k. percent efficiency *E*

   l. second class lever

   m. work *W*

**
-
**

4. Preparation:

   a. Several different stations can be set up by varying the position of the fulcrum, the load, and the effort. Record these positions in the spaces provided in the problem statement in the Laboratory-Experiment Test Instrument.

   b. Provide a newton spring scale having a range suitable for the load and effort.

   c. To eliminate the effect of gravity, set up the apparatus in the horizontal plane and use another newton spring scale as the load.

LABORATORY-EXPERIMENT TEST INSTRUMENT 72

ANALYSIS OF A SECOND CLASS LEVER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are an engineer working for a company that manufactures heavy construction equipment. Your problem is to evaluate simple levers. Determine the ideal mechanical advantage, actual mechanical advantage, and percent efficiency of this second class lever for the following positions of the load, effort and fulcrum with reference to the zero end of the metre stick:

load _____cm; effort _____cm; fulcrum _____cm.

Materials

C-clamp
knife-edge holder
load
3 metre sticks
newton spring scale
paper clips or thread
retort stand, clamp, rod

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 72

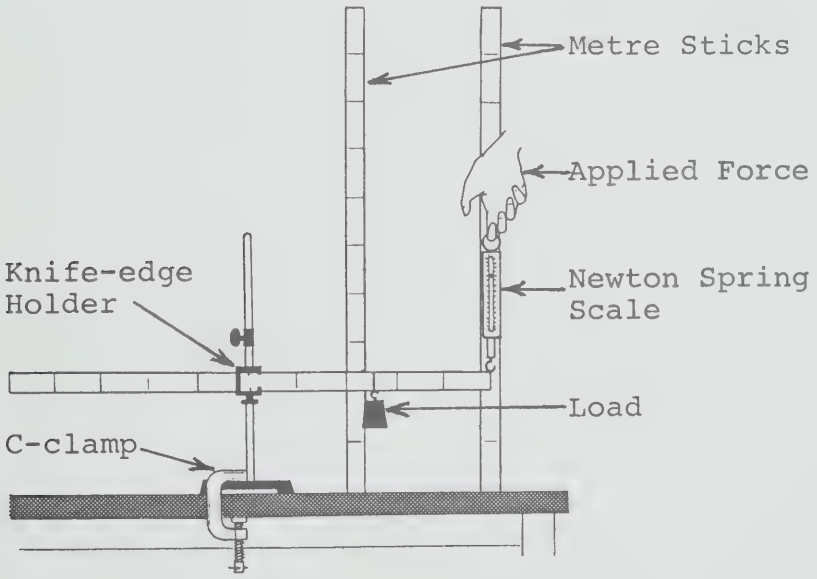
ANALYSIS OF A SECOND CLASS LEVER

Note: Return this sheet to your examiner at the end of the test.

Method

a. Use the newton spring scale to find the force to raise the load at constant speed without the lever. This is the load force.

b. Set up the second class lever, load and spring scale as shown in the diagram. Place the load, effort and fulcrum at the positions specified by your teacher.



c. Pull up on the spring scale and measure and record the force to raise the load using the second class lever. This is the effort force.

d. Measure the distance moved by the effort force as the load moves 0.10 m upward.

e. Determine the actual mechanical advantage of the lever. Show all calculations.

f. Determine the ideal mechanical advantage of the lever. Show all calculations.

ANALYSIS OF A SECOND CLASS LEVER

Method continued

g. Determine the percent efficiency of the lever. Show all the calculations.

h. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 73

ANALYSIS OF A THIRD CLASS LEVER

Notes to the Teacher

391
392
393

1. Suggested schedule: Part A - Experiment Design (10 min)
   Part B - Experiment Report (25 min)

2. Minimum number of students: 2

A2
A8
B3
C4
D3

3. Prerequisite knowledge:

   a. actual mechanical advantage *AMA*

   b. $AMA = \frac{F_l}{F_e}$

   c. distance *d*

   d. $E = \frac{W_l}{W_e} \times 100$

   e. effort *e*

   f. force *F*

   g. fulcrum

   h. ideal mechanical advantage *IMA*

   i. $IMA = \frac{d_e}{d_l}$

   j. load *l*

   k. percent efficiency *E*

   l. third class lever

   m. work *W*

**
-
**

4. Preparation:

   a. Several different stations can be set up by varying the position of the fulcrum, the load, and the effort. Record the positions in the spaces provided in the problem statement in the Laboratory-Experiment Test Instrument.

   b. Provide a newton spring scale having a range suitable for the load and effort.

   c. It may be necessary to stabilize the fulcrum during the experiment.

   d. To eliminate the effect of gravity, set up the apparatus in the horizontal plane and use another newton spring scale as the load.

LABORATORY-EXPERIMENT TEST INSTRUMENT 73

ANALYSIS OF A THIRD CLASS LEVER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you are an engineer working for a company that manufactures heavy construction equipment. Your problem is to evaluate simple levers. Determine the ideal mechanical advantage, actual mechanical advantage, and percent efficiency of this third class lever for the following positions of the load, effort and fulcrum with reference to the zero end of the metre stick:

load _____cm; effort _____cm; fulcrum _____cm.

Materials

C-clamp
knife-edge holder
load
3 metre sticks
newton spring scale
paper clips or thread
retort stand, clamp, rod

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 73

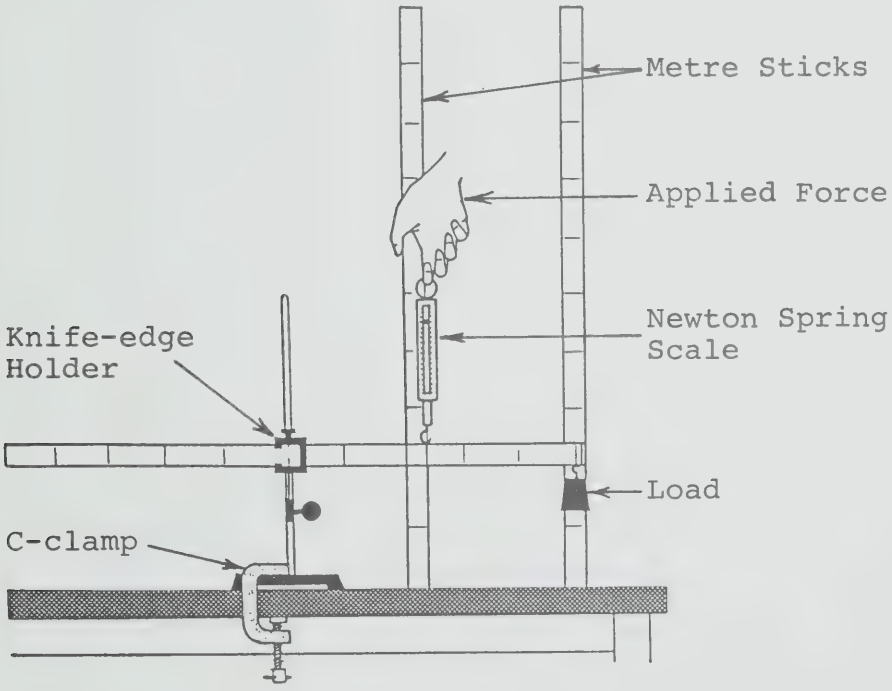
ANALYSIS OF A THIRD CLASS LEVER

Note: Return this sheet to your examiner at the end of the test.

Method

a. Use the newton spring scale to find the force to raise the load at constant speed without the lever. This is the load force.

b. Set up the third class lever, load and spring scale as shown in the diagram. Place the load, effort, and fulcrum at the positions specified by your teacher.



c. Pull up on the spring scale and measure and record the force to raise the load using the third class lever. This is the effort force.

d. Measure the distance moved by the effort force as the load moves 0.10 m upward.

e. Determine the actual mechanical advantage of the lever. Show all calculations.

ANALYSIS OF A THIRD CLASS LEVER

Method continued

f. Determine the ideal mechanical advantage of the lever. Show all calculations.

g. Determine the percent efficiency of the lever. Show all calculations.

h. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 74

ANALYSIS OF AN INCLINED PLANE

Notes to the Teacher

391
392
393

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (25 min)

A2

2. Minimum number of students: 1

A8
B3
C4
D3

3. Prerequisite knowledge:

   a. actual mechanical advantage *AMA*

   b. $AMA = \frac{F_l}{F_e}$

   c. distance d

   d. $E = \frac{W_l}{W_e} \times 100$

   e. effort e

   f. force F

   g. ideal mechanical advantage *IMA*

   h. $IMA = \frac{d_e}{d_l}$

   i. inclined plane

   j. load l

   k. percent efficiency E

   l. work $W = F \cdot d$

**
-
**

4. Preparation:

   a. Preset the slope of the inclined plane to yield the desired result with the block.

   b. Arrange that the weight of the block and the dragging force is within the range of the newton spring scale.

   c. Mark the point x on the inclined plane

LABORATORY-EXPERIMENT

TEST INSTRUMENT 74

ANALYSIS OF AN INCLINED PLANE

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that your construction firm plans to build a ramp for moving heavy construction equipment from one level to another. You are testing inclined planes. Determine the ideal mechanical advantage, the actual mechanical advantage, and the percent efficiency of the inclined plane.

Materials

inclined plane at a preset angle
load (block)
metre stick
newton spring scale
thread

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 74

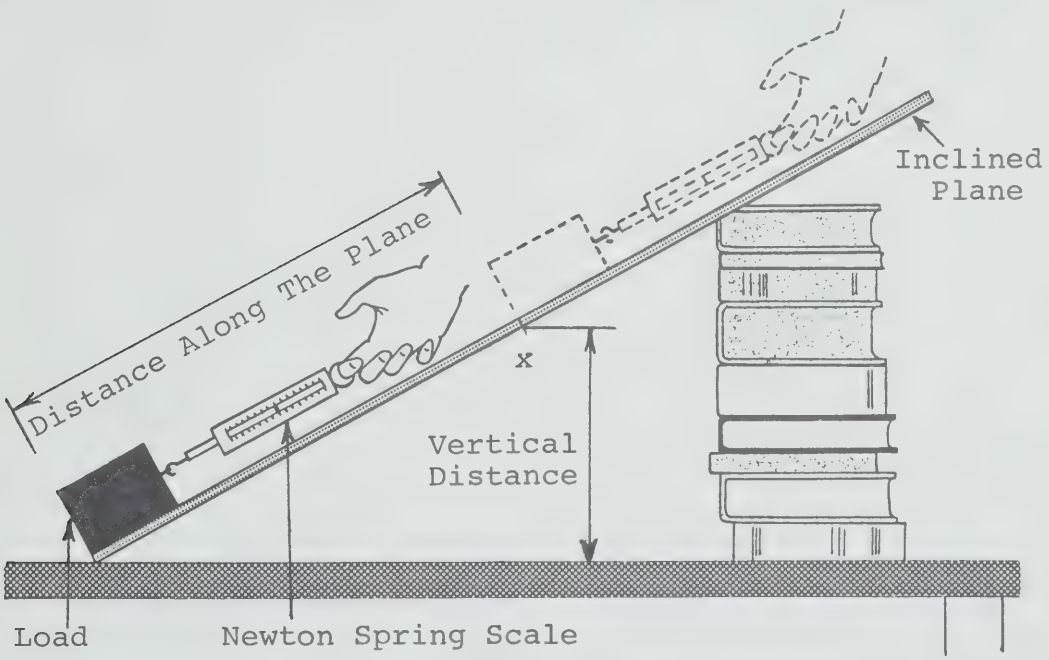
ANALYSIS OF AN INCLINED PLANE

Note: Return this sheet to your examiner at the end of the test.

Method

a. Your teacher has set up the inclined plane at a specific angle to the horizontal. Do not change the angle.

b. Measure and record the distance along the plane to the point x as shown in the diagram.



c. Measure and record the vertical distance from the table surface to the point x.

d. Attach the block to the spring scale. Pull the load at constant speed up the incline to the point x. Record the average force. This is the effort force.

e. Using the spring scale, lift the mass vertically at constant speed from the table surface to point x. Record the average force. This is the load force.

ANALYSIS OF AN INCLINED PLANE

Method continued

f. Determine the actual mechanical advantage of the inclined plane. Show all calculations.

g. Determine the ideal mechanical advantage of the inclined plane. Show all calculations.

h. Determine the percent efficiency of the inclined plane. Show all calculations.

i. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

LABORATORY-EXPERIMENT TEST INSTRUMENT 75

HALF-LIFE

Notes to the Teacher

S17A
IV.2.c

1. Suggested schedule: Part A - Experiment Design (15 min)
   Part B - Experiment Report (25 min)

411

2. Minimum number of students: 1

A2
A5
B3

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-
-

3. Prerequisite knowledge:

   a. background reading
   b. half-life
   c. interpolation
   d. plotting a graph and drawing a line of best fit
   e. radioactive material
   f. use of a scaler and Geiger tube

4. Preparation:

   a. Use a short-lived radioisotope such as Barium-137.
   b. A useful kit for the study of radioisotopes is available from Union Carbide.
   c. A simulation may be used in place of the radioisotope.

5. CAUTION:

   a. WARN THE STUDENTS AGAINST EATING DURING THE TEST.
   b. HAVE THE STUDENTS WASH THEIR HANDS WITH SOAP AND WATER AND RINSE WELL AFTER THE ACTIVITY.

LABORATORY-EXPERIMENT TEST INSTRUMENT 75

HALF-LIFE

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. The test consists of two parts.

In "Part A - Experiment Design" you have ___ min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have ___ min to implement the procedure approved by the examiner and to write up a report.

Problem

Imagine that you work as a physicist for Atomic Energy of Canada Limited. You have discovered a new radioisotope. Your problem is to design and implement a method to determine the half-life of the radioisotope.

Materials

graph paper	scaler and Geiger tube
lead sheet	stopwatch
plastic cup	thermometer
radioisotope	water

CAUTION: DO NOT EAT DURING THE ACTIVITY.
WASH YOUR HANDS WITH SOAP AND WATER AND RINSE WELL AFTER YOU HAVE FINISHED.

Part A - Experiment Design

The examiner will provide you with an answer sheet titled "Part A - Experiment Design". Record your work for Part A on the answer sheet under the appropriate headings.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner.

c) Under the heading "Diagram" draw a labelled diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) When you have finished "Part A - Experiment Design" submit it to the examiner and continue with Part B.

Part B - Experiment Report

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, labelled diagrams, tables of data, and graphs where appropriate.

c) Under the heading "Calculations", show the relevant equation(s) and sample calculations. Include units with numerals throughout the calculations.

d) Under the heading "Accuracy" identify and discuss possible sources of error.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) When you have finished "Part B - Experiment Report" submit it to your examiner.

PROCEDURE SHEET 75

HALF-LIFE

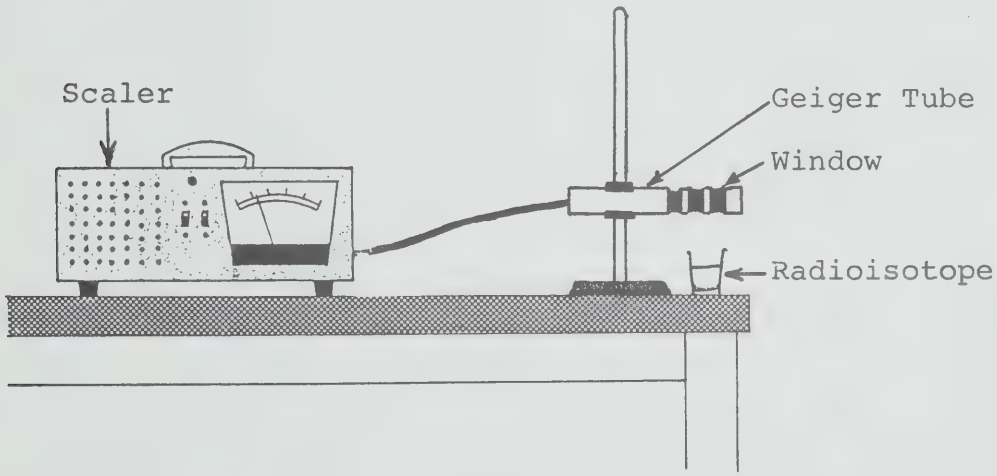
Note: Return this sheet to your examiner at the end of the test.

Method

a. Turn on the scaler and allow it to warm up for a few minutes.

b. Record the background count rate reading, using the detector and scaler, every minute for 5 min. Be certain the radioactive sample is still shielded by the container.

c. Have your instructor place the sample of radioactive material next to the window of the detector shown in the diagram.



CAUTION: DO NOT TOUCH THE RADIOACTIVE SAMPLE. DO NOT EAT DURING THE ACTIVITY. WASH YOUR HANDS WITH SOAP AND WATER AND RINSE WELL AFTER YOU HAVE FINISHED.

d. Count and record the activity of the sample for a 1 min time interval.

e. Wait precisely 1 min, then count and record the activity for another 1 min interval.

f. Repeat this procedure until 6 readings of activity have been recorded.

g. Subtract the background reading from each reading and tabulate the data.

Method continued

h. Plot a graph of the corrected activity readings against time. Plot the activities at 30 s, 150 s, 270 s, 390 s, 510 s, and 630 s.

i. Using the graph, determine the half-life in seconds for the radioactive material.

j. When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

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